BACHELOR THESIS – ME 141502

CONCEPTUAL DESIGN OF MINI LNG SUPPLY CHAIN FOR POWER PLANTS IN WEST BORNEO

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DOUBLE DEGREE PROGRAM OF
MARINE ENGINEERING DEPARTMENT
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember
Surabaya 2017

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DESAIN KONSEP MINI RANTAI PASOK LNG UNTUK MEMENUHI KEBUTUHAN PEMBANGKIT DI KALIMANTAN BARAT

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PROGRAM DOUBLE DEGREE
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Institut Teknologi Sepuluh Nopember
Surabaya 2017

APPROVAL FORM

CONCEPTUAL DESIGN OF MINI LNG SUPPLY CHAIN FOR POWER PLANTS IN WEST BORNEO

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Proposed to Fulfill One of the Requirements for Obtaining a Bachelor Engineering Degree
on
Marine Reliability, Availability, Management and Safety (RAMS) Laboratory
Study Program Bachelor Double Degree of Marine Engineering Department
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember Surabaya

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Surabaya, July 2017

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CONCEPTUAL DESIGN OF MINI LNG SUPPLY CHAIN FOR POWER PLANTS IN WEST BORNEO

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ABSTRACT

Majority of power plants in Khatulistiwa system West Borneo is diesel power plants which has 448.3 MW. Based on *Rencana Operational Tahunan PLN Kalbar,* Total consumption power plants for HFO is 62 million liters/year and total consumption power plants for MFO is 272 million liters/year. To decrease the demand of MFO and HFO in Indonesia, they can be replaced by Liquefied Natural Gas by making use of LNG source in FSRU Lampung or Arun Gas Refinery which has cargo resource about 0.6 MTPA.

On this research, it will be conceptual designed by selecting the most optimal location for mini LNG infrastructure by 3 alternative locations: Siantan, Pontianak and Offshore (Mini FSRU) & four alternatives LNG vaporizer technology using elimination and choice expressing reality (ELECTRE) method. It designs the conceptual of mini LNG supply chain for power plants in West Borneo and determine the conceptual design in terms of economics.

The conceptual design result for the most optimal location of mini LNG plant is in Siantan Regency. Technology of vaporizer is using submerged combustion vaporizer (SCV) technology. The most feasible economics of plant is using self-propelled LNG barge capacity 7500 m^3 with round trip for one-year operation is 49 times per year and using 25 storage tank capacity 300 m^3. The most feasible economics investment is selling LNG with margin, $3.25 per MMBtu (selling in price $10.25 per MMBtu) by source of LNG is in FSRU Lampung. The Value of Net Present Value (NPV) is in amount of $1.520.574, Internal rate return (IRR) is12,33% and payback period is ten years of operation.

Keywords – LNG, Supply Chain, West Borneo, Electre, Economic Feasibility Study

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CONCEPTUAL DESIGN OF MINI LNG SUPPLY CHAIN FOR POWER PLANTS IN WEST BORNEO

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ABSTRAK

Mayoritas pembangkit di sistem Khatulistiwa Kalimantan Barat adalah pembangkit tenaga diesel. Berdasarkan Rencana Operational Tahunan PLN Kalbar, total konsumsi HFO seluruh pembangkit di sistem khatulistiwa adalah 62 juta liter per tahun dan total konsumsi MFO adalah 272 juta liter per tahun. Untuk mengurangi kebutuhan MFO dan HFO di Indonesia, pembangkit gas di sistem khatulistiwa dapat diganti dengan menggunakan LNG dengan memanfaatkan kargo LNG di Arun atau FSRU Lampung yang memiliki cadangan kargo sebesar 0.6 MTPA.

Pada penelitian ini, akan didesain konsep rantai pasok mini LNG di Kalimantan Barat dengan memilih tiga alternatif lokasi yang paling optimal untuk mini LNG plant: Kabupaten Siantan, Kota Pontianak, dan Mini FSRU (Offshore) & memilih teknologi vaporizer yang paling tepat dengan menggunakan metode elimination and choice expressing reality (Electre). Dengan menggunakan solver, akan dikonsep rantai pasok mini LNG yang paling optimal dan akan menentukan keekonomian konseptual design rantai pasok.

Hasil dari konseptual design rantai pasok mini LNG berupa lokasi yang paling optimal untuk pembangunan mini LNG plant yaitu Kabupaten Siantan dengan teknologi submerged combustion vaporizer. Dengan menghitung keekonomian, maka konseptual design yang paling ekonomis adalah dengan menggunakan kapal LNG tongkang ukuran 7500 m3 dengan round trip empat puluh sembilan kali dalam setahun. Margin yang paling optimal dalam investasi ini adalah sebesar $3.25 per mmbtudengan mengambil sumber LNG di FSRU Lampung. Nilai NPV yang di dapat adalah $1.520.574, nilai IRR adalah 12,33% dan Payback period selama 10 tahun operasi.

Keywords – LNG, Rantai Pasok, Kalimantan Barat, Electre, Studi Kelayakan Ekonomi

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PREFACE

Alhamdulillahirobbil 'alamin. Praise is merely to the Almighty Allah SWT for the gracious mercy and tremendous blessing which enables the author to accomplish this bachelor thesis.

This thesis report entitled "Conceptual design of mini LNG supply chain for power plants in West Borneo" is submitted to fulfill one of the requirements in accomplishing the bachelor degree program at Marine Engineering Department, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember Surabaya. Conducting this research study is not possible without all helps and supports from various parties. Therefore, the author would like to thank to all people who has support the author for accomplishing this bachelor thesis, among others:

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Surabaya, 31 July 2017

author

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CHAPTER I
INTRODUCTION

1.1 Background

Based on *Rencana Operational Tahunan (ROT)* PLN Kalimantan Barat 2017, total power plants in Khatulistiwa system of West Borneo is 448.3 MW. Khatulistiwa system is power plants from Pontianak to Sambas which mostly constituted by diesel power plants and the other is gas power plants. Khatulistiwa system power plants are divided into 195.8 MW of PLN power plants, 162.5 MW in Rent Power Plant, 90 MW in SESCO and 1 MW in excess power. The power peak of Khatulistiwa system is shown in table 1.1 below, (Cahya, 2017)

Table 1.1 Projection of Khatulistiwa System in West Borneo
(Cahya, 2017)

Pembangkit	DMN	Unit	%
PLTG SIANTAN	30	1	6.7
PLTD SEI RAYA	24.5	4	5.5
PLTD SIANTAN	28.9	7	6.4
PLTD SEI WIE	10.8	6	2.4
PLTD SUDIRMAN	1.6	2	0.4
SESCO	90.0	1	20.1
MPP PARIT BARU	100.0	4	22.3
PLTD ADAU 1,2	45.0	5	10.0
PLTD ADAU 3	17.0	2	3.8
PLTD AKE	24.0	3	5.4
PLTD PRASTI WAHYU	19.5	11	4.3
PLTD BUGAK PBR	24.0	22	5.4
ALAS KUSUMA	1.0	1	0.2
PLTD SEWATAMA PONTIANAK	32.0	32	7.1
Total	**448.3**	**101.0**	**100.0**

Table 1.1 shows that twelve of fourteen power plants in Khatulistiwa system are diesel power plants and gas power plant including PLTG Siantan and Mobile power Plants Jungkat with total power of 130 MW total. Data from ROT PLN Kalimantan Barat 2017 shows that all gas power plants consume HFO and MFO as energy source, even gas power plants in khatulistiwa system. Total consumption of PLN power plants HFO in Khatulistiwa system is 62 million ton liters per year and consumption of MFO is 272 million ton liters per year which is shown in Table 1.2 below,

Table 1.2 Projection of Power Plants HFO and MFO Consumption (Cahya, 2017)

Pusat Pembangkit			Perkiraan Produksi MFO	Perkiraan Produksi HSD	Perkiraan Produksi EXCESS POWER	Perkiraan Produksi SESCO	Perkiraan Pemakaian MFO	Perkiraan Pemakaian HSD	Perkiraan Pembayaran (Rupiah)*	Biaya Energi (Rp/kWh)
1	**Pembangkit PLN**									
	PLTG	Siantan	-	-	-	-	-	-	-	-
	PLTD	Sei Raya	119,517,450	-	-	-	29,281,775	-	154,683,069,314	1,294
		Siantan	92,404,050	-	-	-	23,101,013	-	121,372,719,675	1,314
		Sei Wie	24,377,050	-	-	-	6,338,033	-	32,958,746,682	1,352
		Sudirman	-	878,100	-	-	-	237,087	1,591,872,366	1,813
	Total PLN		236,298,550	878,100	-	-	58,720,821	237,087	310,606,408,037	1,310
2	**Pembangkit Rental**									
	PLTD	Arti Duta Aneka Usaha 1	358,238,600	-	-	-	84,902,548	-	448,890,161,253	1,253
		Arti Duta Aneka Usaha 2	140,913,500	-	-	-	33,396,500	-	178,787,948,703	1,269
		Asta Keramasan Energi	209,879,000	-	-	-	49,741,323	-	264,321,192,842	1,259
		Prasti Wahyu Parit Baru	-	-	-	-	-	-	-	-
		Bugak Parit Baru	191,404,850	-	-	-	45,937,164	-	267,581,686,056	1,398
		Sewatama Ptk	-	44,530,150	-	-	-	12,245,791	121,010,096,993	2,717
	Total Rental		900,435,950	44,530,150	-	-	213,977,535	12,245,791	1,280,591,085,846	1,355
3	**Excess Power**									
	PLTU	Alas Kusuma	-	-	8,759,700	-	-	-	-	-
4	**SESCO**		-	-	-	788,400,000	-	-	788,400,000,000	1,000
5	**MPP**		-	143,274,805	-	-	-	50,146,182	487,538,412,722	3,403
	Sistem		1,136,734,500	188,683,055	8,759,700	788,400,000	272,698,355	62,629,060	2,867,135,906,604	1,351

*Asumsi harga MFO 3.854 Rupiah/Liter dan HSD 5.418 Rupiah/Liter

Pusat Pembangkit	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Ags	Sep	Okt	Nov	Des	Jumlah
Pembangkit													
Pemakaian MFO	18,248,976	17,395,294	20,567,099	22,218,058	24,055,166	23,484,032	24,340,132	23,762,354	23,867,758	25,150,085	24,321,349	25,288,054	272,698,355
Pemakaian HSD	4,454,391	4,168,924	4,537,609	4,414,166	4,851,066	4,743,814	4,956,042	5,267,623	5,458,706	6,710,855	6,524,506	6,541,359	62,629,060
Pemakaian BBM	22,703,367	21,564,218	25,104,707	26,632,224	28,906,232	28,227,846	29,296,174	29,029,977	29,326,463	31,860,939	30,845,855	31,829,414	335,327,415

Mean economic growth and inhabitant growth in West Borneo until 2025 is 6.8%, meanwhile power peak growth in West Borneo is 10.9%. Based on this data, in 2025, power peak in West Borneo will increase about 1053 MW. Detail of the economic and inhabitant growth in West Borneo is shown in Table 1.3 below,

Table 1.3 Projection of economic growth in west Borneo (Anon., 2016)

Tahun	Pertumbuhan Ekonomi (%)	Penjualan (GWh)	Produksi (GWh)	Beban Puncak (MW)	Pelanggan
2016	6.6	2,100	2,507	416	996,414
2017	7.1	2,347	2,798	464	1,048,816
2018	7.5	2,612	3,111	515	1,102,953
2019	8.0	2,945	3,504	579	1,158,921
2020	6.4	3,271	3,888	641	1,216,902
2021	6.4	3,639	4,321	711	1,277,012
2022	6.4	4,012	4,740	779	1,309,180
2023	6.4	4,445	5,249	861	1,343,215
2024	6.4	4,930	5,812	952	1,379,429
2025	6.4	5,474	6,441	1,053	1,418,152
Pertumbuhan (%)	**6.8%**	**11.2%**	**11.1%**	**10.9%**	**4.0%**

The projection of power peak growth in West Borneo will increase the gap of oil demand from PT. Pertamina as the only institution that responsible to supply & distribute diesel oil to meet the demand in the Republic of Indonesia. It will impact PT. Pertamina import of fuel oil from foreign country. The gap of diesel oil (Figure 1.1) supply-demand of PT. Pertamina (Persero) will be shown below.

Figure 1.1. Projection of fuel oil supply-demand in Indonesia by PT. Pertamina . *(Pertamina, 2015)*

The projection of fuel oil supply-demand by PT. Pertamina (Persero) still having a gap in supply-demand until 2030. This fact is supported by the RUPTL PLN program to develop gas power plant than diesel power plant. From 2016 to 2025, power plants development in Indonesia will be focused on developing gas power plant (PLTG) and Gas Steam Power Plants (PLTGU) to replace diesel power plants using HSD and MFO. The total amount of power plant development until 2025 is 3016 MW for PLTG and 4092 for PLTGU, while there are no developments for diesel power plant until 2025 (Anon., 2016). In this research, conceptual design of mini LNG supply chain for Gas Power Plants in West Borneo (PLTG Siantan and MPP Jungkat) to replace HSD become LNG as a source of energy is offered.

1.2 Statement of Problems

Regarding to background of research, several points of problem statements are identified as follows,

1. How to determine the location of receiving terminal & technology selection of LNG Vaporizer?
2. How to design the concept of mini LNG supply chain in West Borneo with three alternatives of Self Propelled Barge (SPB) LNG capacity?
3. How is the conceptual design in terms of economic?

1.3 Research Limitation

Research Limitations of this study are explained as follows,

1. Design of LNG Receiving Terminal and LNG plant are assumed by three alternative locations in West Borneo: Pontianak City, Siantan regency, and Offshore (mini FSRU).
2. LNG resource is Arun Gas Refinery and FSRU Lampung only.
3. LNG carrier capacity are 7500 m^3, 10000 m^3, and 12000 m^3.
4. LNG regasification technology Selection alternatives are Ambient Air Vaporizer (AAV), Submerged combustion Vaporizer (SCV), Intermediate Fluid Vaporizer (IFV), and Open Rack Vaporizer (ORV).

1.4 Research Objectives

Several objectives of this research are:

1. To select the most optimum location of LNG Receiving Terminal & LNG regasification plant.
2. To design mini LNG supply chain concept in West Borneo by three alternatives of LNG carrier capacity and support components of LNG supply chain components.
3. To determine the minimum Investment cost of mini LNG supply chain in West Borneo by calculating Net Present Value (NPV), Internal Rate Return (IRR) and Payback Period (PP).

1.5 Research Benefits

Several benefits of this research are:

1. To give the concept of ELECTRE method implementation for decision-making progress on the most optimal location of receiving terminal & mini LNG regasification plant technology in West Borneo, Indonesia.
2. To give optimum conceptual design of mini LNG supply chain for power plants in West Borneo Indonesia and support components of mini LNG supply chain.
3. To give recommendation for PLN Indonesia of the conceptual design in economic aspect.

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CHAPTER II
LITERATURE REVIEW

2.1 Liquefied Natural Gas (LNG)

Liquefied natural gas is one of the clean and efficient energy which has lower emmission than fuel oil. Compare to fuel oil, LNG has lower emmission of 25% carbon dioxide emissions, 90% nitrogen emissions and 100% reduction in Sulphur. The volume of natural gas in the gas form compare to Liquefied Natural Gas is 1:600. So, in LNG supply chain from natural gas reserve to power plants, natural gas has different cargo handling because natural gas must be liquefied into -162^{o} celcius for maximum volume in the cargo. Otherwise for power plants, natural gas is consumed in the gas form.

In the physical condition, LNG is colorless, odorless, toxic, and non-corrosive. It can be flammable if it evaporates and contact with ignition source when the amount of gas in the air is between 5% to 15%. If vapor cloud does ignite, the flame speed is slow, namely 3-4 m/s. It means in open space, LNG doesn't explode. LNG is also doesn't pollute soil or groundwater. In open spaces LNG evaporates pretty quick without leaving any residue on water or soil. The density of LNG is 450 kg/m^3. The maximum transport pressure is 4 psi or 25 kPa. Natural gas dominantly consists of methane (CH4), the simplest hydrocarbon compound. Typically, LNG is 85 to 95-plus percent methane, along with little amount of ethane, even less propane and butane, and trace amounts of nitrogen (Figure 2. 1) (Laboratory, 2005)

Natural Gas is one of the energy reservations developed by Indonesia government as an alternatives to change the consumption of Heavy Fuel Oil and Medium Fuel Oil to make the country independent from fuel oil. LNG Infrastructure development has developed significantly such as in the form of mini LNG plant in Benoa Bay, Bali to supply Gas power plant for 30 million metric standard cubic feet per day (mmscfd). In RUPTL PLN program, Indonesian government has established a policy to reduce the fuel oil consumption in diesel power plants from 10% become 6%. This program can be realized by investing mini LNG plant infrastructure in provinces that utilizes diesel power plants such as West Borneo.

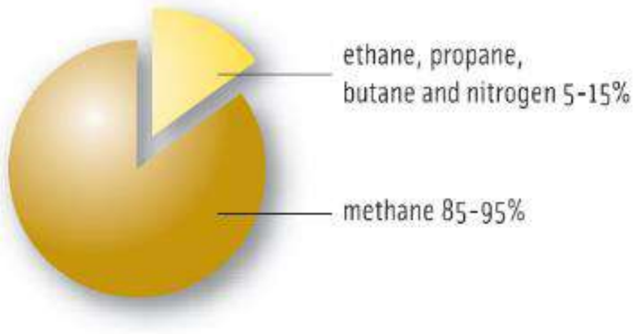


Figure 2. 1 LNG Physics
(Laboratory, 2005)

2.2 Mini LNG Supply Chain

The alternative to select mini LNG plant is a solution of distribution for city or regency with small LNG demand. The investment of mini LNG infrastructure is not as expensive as large-scale LNG supply chain. Each of the components on small LNG supply chain such as LNG liquefaction plant, LNG receiving Terminal, LNG Storage tank, LNG regasification also have small capacity to supply several industries, power plants, households, etc., with the capacity of 0.2 to 1 metric ton LNG per annum (MTPA) (Andreau, 2016). Large LNG carrier which carries large cargo capacity can conduct ship-to-ship cargo transfer to mini LNG carrier. Large LNG carrier can also unload the cargo to the receiving terminal and storage tank, then mini LNG carrier will load the LNG and distribute to small receiving terminal. Another alternative is by LNG carrier loading LNG from small liquefaction plant then carrying it to small receiving terminal & storage tank. Another thing that can be done is Large LNG carrier conducts ship-to-ship cargo transfer to FSRU/FSU then mini LNG carrier conducts ship-to-ship cargo transfer with FSRU. Onshore distribution also has more alternatives. LNG is distributed by truck, pipe, and locomotive. Truck and locomotive are done by cryogenic tank. All alternatives depend on the distance of supply chain components and geographic condition of end user.

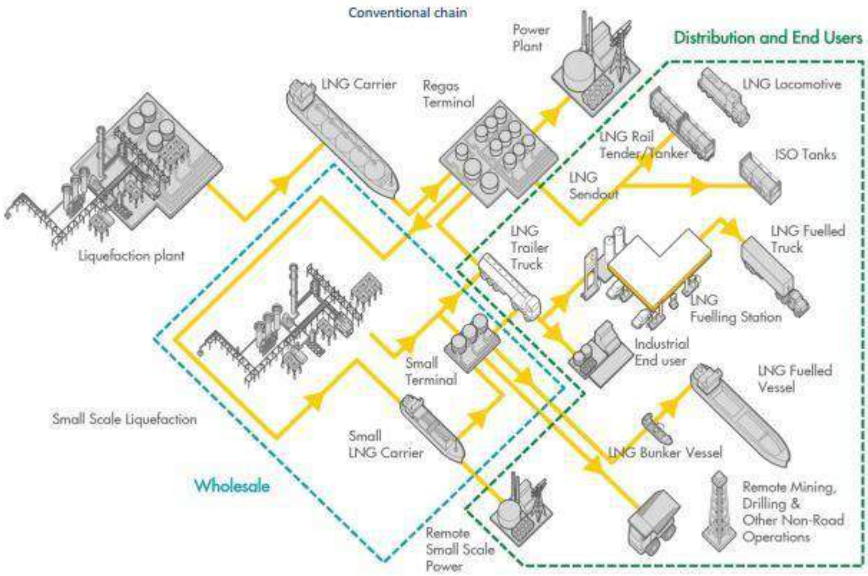


Figure 2. 2 Mini LNG Supply Chain & Distribution
(Union, 2015)

2.2.1 FSRU Lampung

FSRU or Floating Storage and Regasification Unit is a floating infrastructure for LNG and then regasification the LNG become gas form. FSRU has the following basic functions such as Receipt of LNG brought in by another LNG carrier, Storage of LNG, Pressurization & regasification of LNG into gas, Metering and send-out of gas into on-shore gas pipeline grid. PGN FSRU Lampung has regasification maximum in amount of 240 mmscfd. In 2016, FSRU lampung is supplied 14 cargos from tangguh gas refinery for being distribued to several consumen including Power Plants, Commercial, and household for west indonesia. The total capacity of FSRU lampung is 84054 t. If Tangguh gas reserve send to FSRU lampung in amount of 14 cargos per year, it means about 1.2 MTPA LNG can be consumed in west indonesia. In fact, FSRU lampung only send 35% of cargo to west indonesia, so there are potential to support mini LNG plant in West Borneo. PT Perusahaan Gas Negara (Persero) rent FSRU Lampung from Hoegh LNG Lampung with the 20-year contract. (Tatit, 2014)

Figure 2.3 FSRU Lampung
(Tatit, 2014)

2.2.2 Arun Gas Refinery

Arun Gas Refinery is 800 nm from Pontianak with 6 LNG Plant, total capacity of 12.5 MTPA with 5 LNG Storage Tank, total capacity of 636000 m^3 and 2 LNG Jetty 80000 DWT. Arun LNG plant covers an area of 271 ha, located in Blang Lancang-Lhokseumawe and 30 km from Arun gas field in Lhoksukon. Natural gas resource contained in reservoir is estimated at 18 trillion ft^3, Natural gas will be processed or distributed in six natural gas liquefaction trains, but with the content of natural gas now dwindling, PT. Arun only operating four LNG trains with area of 92.5 km^2.

Figure 2.4 Arun Gas Refinery
(Gas, 2015)

2.2.3 LNG Carrier

2.2.3.1 Mini LNG Carrier

LNG carrier installs cargo handling system which has function to chill LNG to become liquid in the temperature of -160^{o} celcius. On propulsion system, LNG carrier installing gas turbine as a primary mover. LNG in cryogenic tank will release boil off gas (BOG) because temperature is increasing in the tank. The total of boil off gas release is 0.15% per day. So, gas turbine is installed as a prime mover because gas turbine can use boil off gas as additional energy and efficient energy. On LNG containment system, LNG carrier is divided based on IGC code into two: independent tank and integrated tank. Independent tank is LNG tank which is separated from hull structure of LNG carrier while Integrated tank is combined with hull structure. Independent tank is IHI-SPB tank and Moss Spherical Tank, while integrated tank is GTT tank. Mini LNG carrier cargo capacity today is divided into: Shinju Maru (2500 m^3), Anthony Veder (6500 m^3), Coral Methane (7500 m^3) Norgas (10000 m^3), etc.

Figure 2.5 Anthony Veder mini LNG carrier 6500 m3
(Shipbuilding, 2013)

2.2.3.2 SPB LNG Barge

Self Propelled Barge (SPB LNG) is a transport ship that has a flat hull and generally tugged by tugboat for sailing on a lower draft or shallow waters, such as river in Indonesia. Self Propelled Barge system is not equipped with boil off gas (BOG) release, so the distance is limited from the maximum limit of compensation LNG tank to the BOG. Therefore, Self Propelled LNG Barge (Figure 2.6) is suitable for LNG transport at close range, where the advantage is no need to install unloading unit on board. Because LNG is distributed in the form of tube/skid tank, when SPB LNG is in receiving Terminal, LNG can be directly transported to customers by piping and receiving terminal is given facilities of LNG unloading.

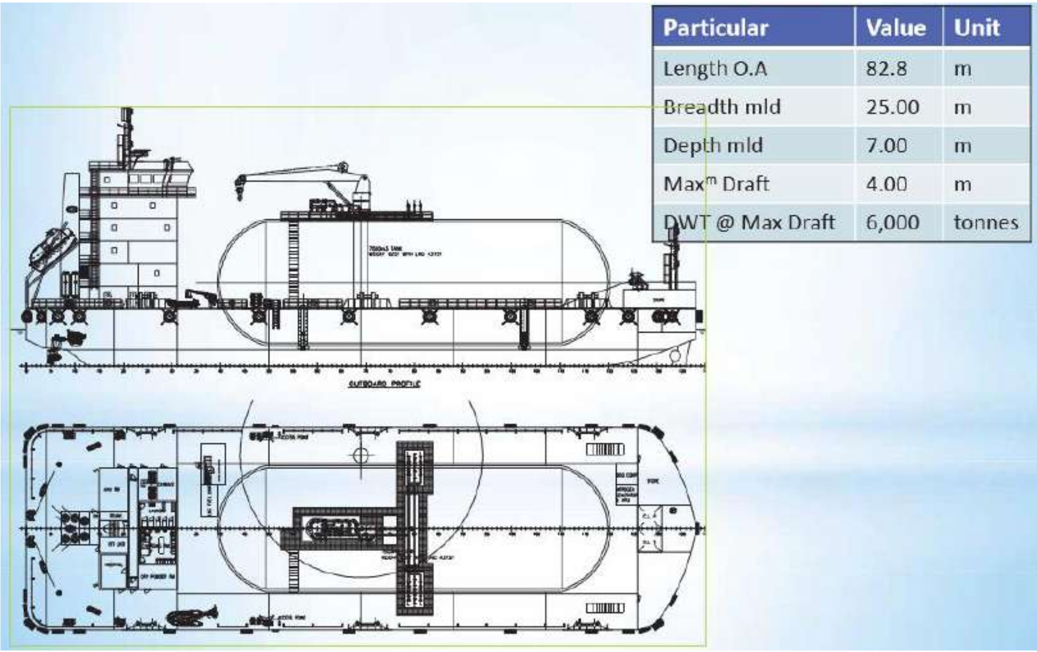


Figure 2.6 KOMTech Self Propeled LNG Barge 7500 m3
(Bashar, 2014)

2.2.2.3 Mini LNG carrier & SPB LNG Comparison

Mini LNG carrier and SPB LNG barge have several advantages and disadvantages as LNG carrier. Mini LNG carrier has deeper draft than SPB LNG which make Mini LNG carrier cannot sail in shallow water. While Mini LNG carrier has offloading system for ship-to-ship cargo transfer. SPB LNG barge has no boil off gas systtem release. SPB LNG uses skid tank separated from LNG carrier hull which means that SPB LNG has to install unloading system for ship-to-ship cargo transfer. Table 2.1 shows advantages and disadvantages of Mini LNG carrier & SPB LNG.

Table 2.1 Advantage & Disadvantage Mini LNG Carrier & SPB LNG
(Satria, 2015)

Mini LNG Carrier	Self Propelled LNG Barge
Support BOG Release	Doesnt Support BOG Release
Support Unloading System	Doesnt Support Unloding System
Draft for Deep Water	Draft for Shallow Water
Higher cost Investment	Lower cost Investment
For Small demand LNG	Can carry medium demand LNG

2.2.4 LNG Transfer

LNG transfer is an activity of loading and unloading LNG by ship. LNG transfer is divided into two, namely ship-to-ship cargo transfer and loading arm.

1. Shore to Ship Cargo Transfer

Shore to ship cargo transfer uses mooring system for berthing in terminal. When ship is in receiving terminal, LNG carrier will receive cargo from onshore through loading arm. Loading arm is using a system which will connect to connecting shore. After connecting, then LNG can be flowed to LNG carrier. Loading arm is equipped with penumatic & hydraulic system as a fluid mover thus loading arm can be moved automatically. Safety system on loading arm is using Emergency Shutdown (ESD) system. This system is used when there is any movement of loading arm & connecting shore which will potentially create a leakage.

Figure 2.7 Shore to Ship Cargo Transfer by Loading Arm
(KlawLNG, 2017)

2. Ship to Ship Cargo transfer

Ship-to-ship cargo transfer not using mooring system to moor the ships. In general, ship-to-ship cargo transfer is operated by rope that tie from ship to ship to make the stable both two ships. For safety operation, tie fender will be used between ship to avoid collision. Ship-to-ship cargo transfer is using flexible hose that connect sister ship to mother ship. Generally, this instrument is used for small LNG carrier for time efficiency.

Figure 2.8 Ship to Ship Cargo Transfer by Loading Arm
(KlawLNG, 2017)

The latest flexible hose technology is created from dyneema fiber. This technology claims as the strongest fiber in the world, where fifteen times stronger than iron and has lower weight than water. This flexible hose can be used in extreme area or weather while conducting ship-to-ship cargo transfer between ships. This technology has also higer reliability than flexible hose. This flexible hose is completed by leakage monitoring system, quick connect/disconnect structure, and has higher time efficiency in LNG transfer operational. (Satria, 2015)

2.2.5 LNG Receiving Terminal & Storage Tank

LNG receiving terminal (Figure 2.9) is a facility which functions to receive and store LNG and have facility to send out rate to end user. Location of receiving terminal must be safe, secure, have access to the sea, and enough space for ship to berth in terminal. If it is not enough for ship berthing because of the draft, then receiving terminal should install trestle or catwalk in the terminal to keep the draft sufficient for ship. Local terminal has a storage tank size of 100–20000 m^3, and located by the sea shore or river. The storage is built as bullet tanks. These terminals are often built primarily as bunker facilities for ships or small LNG carrier for berthing, but they can also include additional services such as truck and container loading to facilitate distribution of LNG in liquid form. In larger sizes, a regasification unit supplying a local gas pipeline can also be added as an alternative. (Wartsila, 2016)

Figure 2.9 LNG Receiving Terminal and Storage Tank
(Wartsila, 2016)

Based on wartsila LNG solutions 2016, LNG storage tank is made from cryogenic material which can maintain the temperature (-160^{o} celcius) of LNG. LNG storage tank is divided into vertical and horizontal tank. Vertical tank (Figure 2.14) has characteristics of small footprint, heavy foundations, and size up to approximately 300 m^3 in wartsila project guide. While horizontal tank (Figure 2.15) has characteristics of large footprint and light foundations and approximately has 1200 m^3 in wartsila project guide. (Wartsila, 2016)

Figure 2.10 Horizontal & Vertical LNG storage tank
(Wartsila, 2016)

2.2.6 LNG Regasification Plant

There are four types of regasification classified according to the media.

2.2.6.1 Open Rack Vaporizer (ORV)

Open Rack Vaporizer (ORV) is a heat exchanger which uses seawater as source of heat. The proper seawater temperature for ORV operation is above 5° Celsius. ORV units are generally constructed of aluminum alloy for mechanical strength suitable to operate at cryogenic temperature. The material has high thermal conductivity which is effective for heat transfer equipment. The tubes are arranged in panels, connected through the LNG inlet and the re-gasified product outlet piping manifolds and hung from a rack (Figure 2.11). For large regasification terminals where significant amounts of water are required, in-depth evaluation and assessment of the seawater system must be performed. Often, late design changes are very difficult and costly to be implemented, thereby, the key issues and design parameter must be established early in the project, such as seawater quality for operating an ORV system, seawater containing significant amounts of another particle (Metal, Sand, etc), proper seawater intake filtration system must be designed to prevent silts, sands and sea life from reaching the seawater pumps and exchangers. (Patel, 2013)

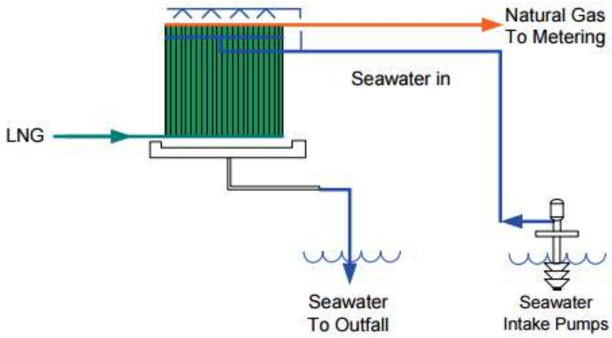


Figure 2.11 Open Rack Vaporizer Flow Scheme
(Patel, 2013)

2.2.6.2 Submerged Combustion Vaporizers (SCV)

Submerged Combustion Vaporizers system (Figure 2.12) is LNG flows through a stainless-steel tube coil that is submerged in water bath heated by direct contact with hot flue gases from a submerged gas burner. Flue gases are sparked into the water using a distributor located under the heat transfer tubes. The sparking action promotes turbulence, resulting in a high heat transfer rate and high thermal efficiency (over 98%). The turbulence also reduces deposits or scales that can build up on the heat transfer surface. Since the water bath is always maintained at a constant temperature and has high thermal capacity, the system copes very well with sudden load changes and can be quickly started and stopped. The bath water is acidic as the combustion gas products (CO_2) are condensed in the water. Caustic chemical such as sodium carbonate and sodium bicarbonate can be added to the bath water to control the pH value and to protect the tubes against corrosion. The excessive combustion water must be neutralized before being discharged to the open water.

To minimize NOx emissions, low NOx burners can be used to meet the 40 ppm NOx limit. NOx level can be further reduced by using Selective Catalytic Reduction (SCR) system to meet the 5-ppm specification if more stringent emission requirements is needed, at a significant cost impact. SCV unit is a trusted equipment and is very reliable with very good safety records. Leakage of gas can be quickly detected by hydrocarbon detectors which will result in a plant shutdown. There is no danger of explosion, since the temperature of the water bath always stays below the ignition point of natural gas. The controls for the submerged combustion vaporizers are more complex compare to the open rack vaporizers (ORV). SCV has more instruments, such as the air blow, sparking piping and burner management system which must be maintained. SCVs are compact and do not require much plot area compare to the other vaporizer options. (Patel, 2013)

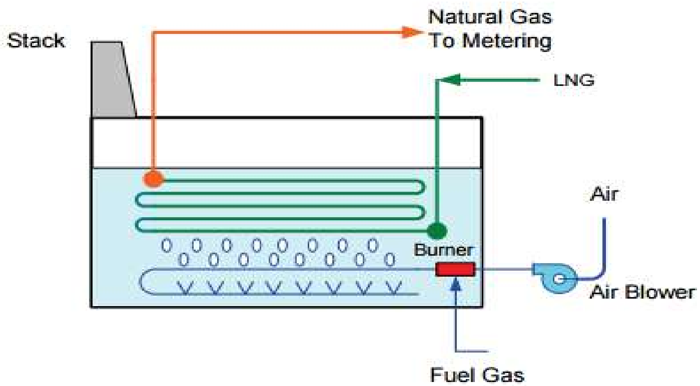


Figure 2.12 Submerged Combustion Vaporizer Flow Scheme
(Patel, 2013)

2.2.6.3 Ambient Ai Vaporizer (AAV)

Direct ambient air vaporizers are used in cryogenic services, such as in air separation plants. They are vertical heat exchanger and are designed for icing on the tube side and require defrosting. They have been used for peak shaving plants and smaller terminals. When compared to other vaporizer options, they require more vaporizer units. AAV (Figure 2.13) consists of direct contact, long, vertical heat exchange tubes that facilitate downward air draft. This is due to the warmer, less dense air at the top being lighter than the cold, denser air at the bottom. Ambient air vaporizers utilize air in a natural or forced draft vertical arrangement. Water condensation and melting ice can also be collected and used as a source of service/potable water. To avoid dense ice buildup on the surface of the heat exchanger tubes, deicing or defrosting with a 4-8-hour cycle is typically required. Long operating cycles lead to dense ice on the exchanger tubes, requiring longer defrosting time. Defrosting requires the exchanger to be placed on standby mode, and can be completed by natural draft convection or force draft air fans. The use of force draft fans can reduce the defrosting time but would require additional fan horsepower. The reduction in defrosting time is typically insignificant as the heat transfer is limited by the ice layers which act as an insulator.

Fog around the vaporizer areas can pose visibility problem, which is generated by condensation of the moist air outside. The extent of fog formation depends on many factors, such as the separated distances among units, wind conditions, relative humidity and ambient temperatures. The performance of ambient air vaporizers depends on the LNG inlet and outlet conditions and more importantly, site conditions and environment factors, such ambient temperature, relative humidity, altitude, wind, solar radiation, and proximity to adjacent structures. Ambient air heater is advantageous in hot climate equatorial regions where ambient temperature is high all round. (Patel, 2013)

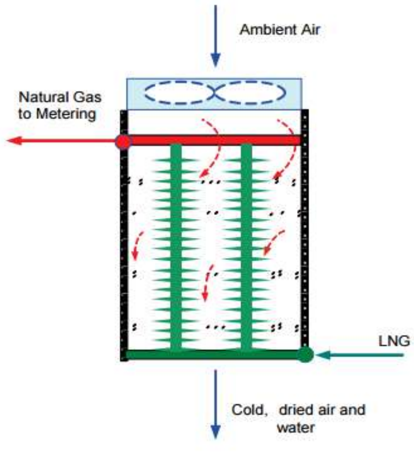


Figure 2.13 Ambient Air Vaporizer Flow Scheme
(Patel, 2013)

2.2.6.4 Intermediate Fluid Vaporizer – Glycol Water (IFV)

This LNG vaporizing via intermediate fluid utilizes Heat Transfer Fluid (HTF) in a closed loop to transfer heat to vaporize LNG. The types of Heat Transfer Fluids are typically utilized for LNG vaporization is Glycol-Water. This system typically uses glycol-water as an intermediate heat transfer fluid (Figure 2.14). Heat transfer for LNG vaporization occurs in a shell and tube exchanger. Warm glycol-water flows through the intermediate fluid vaporizers where it rejects heat to vaporize LNG. These glycol-water IFVs are very compact exchangers (vertical shell and tube design) due to the high heat transfer coefficients and large temperature approach. Some of the operating plants utilize air heater and reverse cooling tower as the source of heat. There are several options to warm the glycol-water solution prior to recycling it back into the shell and tube LNG vaporizers, such as air heater, reverse cooling tower, seawater heater and waste heat recovery system or fired heater.

Using air for heating will generate water condensate, especially in the equatorial regions. The water condensate is rain water quality which can be collected and purified for in-plant water usage and/or exported as fresh raw water. With the use of intermediate fluid such as glycol-water, the glycol temperature can be controlled at above water freezing temperature, hence avoiding the icing problems. Similarly, reverse cooling tower design, which extracts ambient heat by direct contact with cooling water via sensible heat and water condensation, will require an intermediate fluid. The heat of the cooling water can be transferred to the intermediate fluid by a heat exchange coil. Seawater may also be used. However, the use of seawater is more prone to exchanger fouling, and the exchanger (plate and frame type) need to be cleansed periodically. The plate and frame exchangers are very compact and low in cost. Typically, spare seawater exchangers are provided for this option. (Patel, 2013)

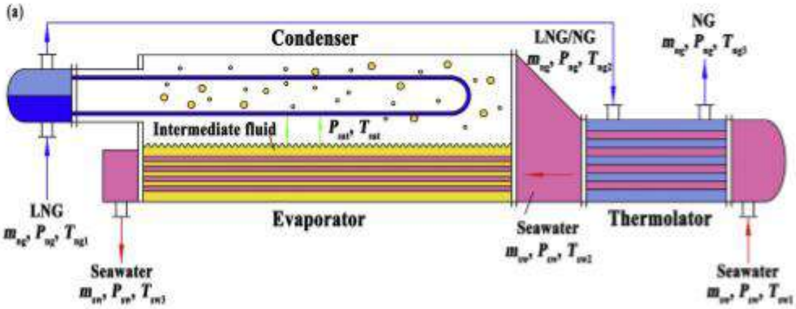


Figure 2.14 Glycol-water Intermediate Fluid Vaporizer – Glycol Water (Patel, 2013)

2.3 Power Plants in West Borneo

Interconnect system in West Kalimantan consists of 448.3 MW power plants that spread from Pontianak to Sambas. The majority interconnect systems that still consume HFO and MDO as fuel will lead to the country's dependence on imported oil from Indonesia abroad. Several power plants below (Table 2.1) will convert from consume diesel oil to become LNG. The total power of power plant is 130 MW while the amount of LNG demand is 16 mmscfd. So, total of LNG demand to supply 130 MW power plants is 0.180 MTPA per year.

2.3.1 LNG Demand for Power Plants

Gas power plants in Khatulistiwa System as follows still consume diesel oil as source of energy that will be changed with LNG in amount of 26 mmscfd. Power plants which will be supplied is PLTG Siantan in amount of 30 mw, and MPP Jungkat Parit Baru for 100 MW. West Kalimantan population growth of 6.8% per year make the government start to convert plants into fuel gas. In addition, the government program to build gas-fired power generation and steam power in anticipation of peak loads increasing from year to year.

Table 2.2 LNG Demand for Power Plants
(Cahya, 2017)

Power Plant	Power (MW)	LNG demand (mmscfd)	Fuel	Status
PLTG MPP Jungkat	100	20	Diesel Oil	Operation
PLTG Siantan	30	6	Diesel Oil	Operation
Total	130	26		

Figure 2.15 PLTG Siantan
(Pontianakpost, 2017)

Figure 2.16 PLTG MPP Jungkat 100 MW
(Pontianakpost, 2017)

2.3.2 Alternative location for LNG Regasification Plant

2.3.2.1 Regency of Siantan

First Alternative location for LNG regasification Plant is Siantan. Siantan is located in the coordinate of 0.054846^0 S, 109.204387° E, located in north of Pontianak city. This city is passed by Kapuas river and the location of Pontianak city is shown in Figure 2.17.

Figure 2.17 Alternative location 1 (Regency of Siantan)

2.3.2.2 City of Pontianak

Second Alternative location for LNG regasification Plant is Pontianak. Pontianak is located in the coordinate of 0.004822^{0} S, 109.304926^{o} E which has area of 107,82 km^{2}. This city also passed by Kapuas river and location of Pontianak city is shown in Figure 2.18.

Figure 2.18 Alternative location 2 (Pontianak City)

2.3.2.3 Offshore (Mini FSRU)

Third alternative for LNG regasification Plant is offshore using mini FSRU. The location of Mini FSRU is 22 km west from MPP Jungkat in South China Sea Pontianak in the coordinate of 0.0072853^{0} S, 108.965844^{o} E (Figure 2.19).

Figure 2.19 Alternative location 3 (Offshore with Mini FSRU)

2.4 Multi Criteria Decision Making (MCDM)

Multicriteria decision-making is a decision-making method to establish the best alternative from several alternatives based on certain criteria. Criteria are usually in the form of measures, rules or standards used in decision making. Based on its aim, multicriteria decision-making can be divided into two models, namely multi attribute decision-making and multi objective decision-making. Multi attribute decision-making is used to solve problems in discrete space. Therefore, these models are typically used to conduct the assessment or selection of some alternatives in limited quantities. While the multi objective decision-making is used to solve problems in continuous space. In this case, multi criteria decision-making method is Elimination and Choice Expressing Reality (Electre). (Syeril Aksheraeri, 2016)

2.4.1 Elimination & Choice Expressing Reality (ELECTRE)

Electre is the acronym of Elimination Et Choix Traduisant la réalité or in English means Elimination and Choice Expressing Reality. Electre is one of multiple criteria decision-making methods based on the concept of outranking using pairwise comparison of alternatives based on any appropriate criterion. ELECTRE methods used in condition where the alternative is less appropriate with the eliminated criteria and new appropriate alternative can be generated. An alternative is said to dominate the other alternatives if one or more criterias exceed (compared to the other alternative criteria) and same with the other remaining criteria. The steps undertaken in problem solving using ELECTRE method is as follows:

1. Normalized decision matrix

In this procedure, each attribute is converted into comparable value. Any normalization of the values xij can be done by formula

$$\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \text{ for i = 1,2,3,.... m and j = 1,2,3... n} \quad (2.1)$$

so, the normalized results obtained matrix R,

$$R = \begin{matrix} r_{11} & r_{12} & r_{1n} \\ r_{21} & r_{22} & r_{2n} \\ r_{m1} & r_{m2} & r_{rmn} \end{matrix} \quad (2.2)$$

R is a matrix that has been normalized, where m stated alternatives, n is the stated criteria and rij is the normalized measurement of the alternative choices to-i in conjunction with the criteria for all j.

2. Weighted normalized matrix

Once normalized, each column of the matrix R is multiplied by the weights (wj) determined by the decision maker. Thus, the weighted normalized matrix is V = W.R written as:

$$V = R \times W$$

$$\begin{matrix} v_{11} & v_{12} & v_{1n} \\ v_{21} & v_{22} & v_{2n} \\ v_{m1} & v_{m2} & v_{mn} \end{matrix} = \begin{matrix} w_1 r_{11} & w_2 r_{12} & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & w_n r_{2n} \\ w_1 r_{m1} & w_2 r_{m2} & w_n r_{mn} \end{matrix} \quad (2.3)$$

where W is

$$w = \begin{matrix} w_1 & 0 & 0 \\ 0 & w_2 & 0 \\ 0 & 0 & w_n \end{matrix} \quad (2.4)$$

3. Determine the set of concordances and discordances index

For each pair of alternatives k and l (k, l = 1,2,3, ..., m and k ≠ l) A set of criteria is divided into two subsets, namely concordance and discordance. Alternative criteria is included in concordance if: C_{kl} = { j, v_{kj} >= v_{ij}}. Instead, complementary subsets of concordance is set discordance, namely when D_{kl} = { j, v_{kj} < v_{ij}}.

4. Calculate the matrix of concordance and discordance

a. Calculating the matrix concordance

To determine the value of the elements in the matrix concordance is by adding weights included in the set of concordances, in mathematical is as follows:

$$C_{kl} = \sum_{je} C_{kl} \tag{2.5}$$

b. Calculating the matrix discordances

To determine the value of the elements in the matrix discordances is by dividing the maximum difference of criteria that included into subsets discordances with a maximum difference of the value of all the criteria, it mathematically written as follows:

$$d_{kl} = \frac{\max\{|v_{kj} - v_{ij}|\}}{\max\{|v_{kj} - v_{ij}|\}} \tag{2.6}$$

5. Determine the dominant matrix of concordance and discordances

a. Calculating the dominant matrix concordance

The matrix F as the dominant matrix concordance can be built with the help of threshold value, by comparing the value of each matrix element concordance with the threshold value.

$$c = \frac{\sum_{k=1}^{m}\sum_{i=1}^{m} c_{kl}}{m\,(m-1\,)} \tag{2.7}$$

so, that the elements of matrix F are determined as follow:

$$f_{kl} = \{\frac{1, if\ c_{kl} \geq c}{0, if\ c_{kl} < c} \tag{2.8}$$

b. Calculating the dominant matrix concordance

Matrix G as the dominant matrix can be built with the help discordance threshold value:

$$d = \frac{\sum_{k=1}^{m}\sum_{i=1}^{m} d_{kl}}{m\,(m-1)} \tag{2.9}$$

and elements of matrix G is determined as follows:

$$g_{kl} = \{\frac{1, if\ d_{kl} \geq c}{0, if\ d_{kl} < c} \tag{2.10}$$

6. Determine aggregate dominance matrix

Matrix E as aggregate dominance matrix is a matrix which each element is the multiplication between matrix element F with the corresponding elements of matrix G, mathematically expressed as:

$$E_{kl} = f_{kl} \times g_{kl} \tag{2.11}$$

7. Elimination less favorable alternative

Matrix E gives the preferred order of each alternative, if the alternative Ak is the better alternative than Al. Thus, the line in matrix E which has the least number can be eliminated. Thus, the best alternative is an alternative that dominates other alternatives. (Syeril Aksheraeri, 2016)

2.5 Linier Programming using Excel Solver

Solver is provided by MS Excel as a tool to find the optimal value in a formula in an Excel worksheet cell (or so-called target cells). The expected value can be the maximum value, minimum value or a specific value. Microsoft Excel application program has multiple devices (add-in) that can be used for data analysis process. They are add-ins that are used to solve simple to complex cases in a Microsoft Excel worksheet. Solver can calculate the value needed to achieve the results set forth in other cells. In other words, the solver can handle problems involving many variables cells and to help find a combination of variables to minimize or maximize the value of the target cell. Mathematical modeling in solver consists of input, decision variables, constraints and objectives. These factors will then be processed in the set of equations. Solver is part of a sequence of commands that are interconnected directly or indirectly in a group of the formula in a target cell.

Solver program will produce three reports: answer, sensitive and limit. Answer report presents answers on issues that are processed, including objective function, constraints and decision variables. Limits report tells how much the values of cells variables can be raised or lowered without exceeding the specified limits. For each variable, the report defines the optimal value also the lowest and highest value that can be used without violating the restrictions that have been determined. Sensitivity report contains information on the target cell sensitivity or sensitivity to change in the approved limits. Sensitivity analysis is conducted to determine the effect of data changing, which is based on the limits to get the expected values.

2.6 Economic Study

Economics Study is done to measure investment value that will give us the rate of financial profit or loss. The parameters used in measuring profit/loss in this research include Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP).

2.6.1 Net Present Value

Net Present Value (NPV) approach gives the project contribution toward the total value of a firm which means positive contribution from a project will directly add value to the firm or vice versa. This unique characteristic utilizes NPV criterion for selecting projects consistent with the financial objective of maximizing the shareholders' wealth. When using NPV criterion for evaluating project, we need to pay attention to the following aspects:

- All relevant and related cash flows of a project should be included in the computation of its NPV
- The project's NPV reflects its contribution to the present value
- The NPV of a project is inversely related to its discount rate
- The required of rate return used to discount a project's cash flows should reflect the project's cost capital and risk

Net Present Value of a project can be expressed as:

$$\text{NPV} = \sum_{t=0}^{n} \frac{bt-ct}{(1+i)^2} \tag{2.12}$$

where:

- NPV = Net Present Value of the project
- Bt = benefit to be received in period t
- Ct = (After Tax) Cash Flow to be received in period t
- n = The number of total periods for discounting life of project
- 1/(1+i) = The discount rate (i.e required rate of return)
- t = The number of period during which the discounting occurs

NPV of project is inversely related to the discount rate or the required rate of return on investment. A sketch of relationship associated with a project based on different discount rates is referred to as project's NPV profile, shown in Figure 2.20. (Dewangga, 2016)

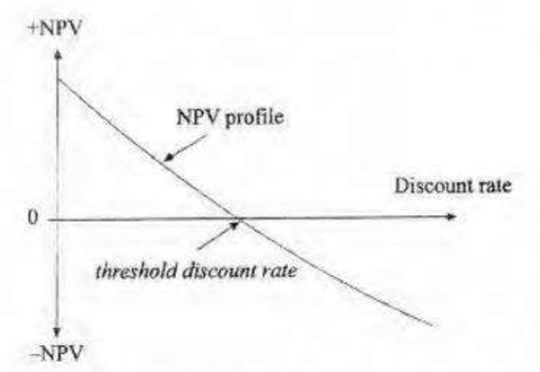


Figure 2. 20 NPV Profile
(Dewangga, 2016)

2.6.2 Internal Rate Return

Intenal Rate Return (IRR) criterion is an evaluation approach which is very similar with NPV method discussed in the previous section. It also discounts the cash inflows and cash outflows of the project.

The main difference between NPV and IRR approaches is that the latter discounts project's cash flows at a rate so as to equate the present value of cash inflows to the present value of the cash outflows, that is IRR approach sets a precondition so when the project's NPV equals zero, the discount rate used to discount the project's cash flows is equal to its internal rate of return. A project is feasible economically if IRR is higher than the capital cost plus risk premium of the project plus benefit; as shown in the formula:

$$IRR = i_1 + \frac{npv_1}{npv_1 - npv_2}(i_1 - i_2) \tag{2.13}$$

where,

IRR = Internal Rate Return of the project
i_1 = Discount rate to produce positive NPV
i_2 = Discount rate to produce negative NPV
NPV_1 = NPV Positive
NPV_2 = NPV mg

2.6.3 Payback Period

Payback Period criterion is an evaluation approach to compare the initial cash outlay with the subsequent annual cash inflows of the project in order to determine the number of years needed to recover the initial investment. Under this approach the shorter the payback period, the more attractive the project. The decision criterion is to accept a project if its payback period is not longer than the maximum tolerable period, which is arbitrarily decided by the firm.

$$PP = (n - x) + (-b/c) \tag{2.14}$$

where:

PP = Payback period
n = year where cash flow couldnt complete the first investment
x = time to build the ship (year).
b = value absoulut *cummulative cashflow discounted* in year to n.
c = nilai *cashflow discounted* pada tahun ke n+

CHAPTER III
METHODOLOGY

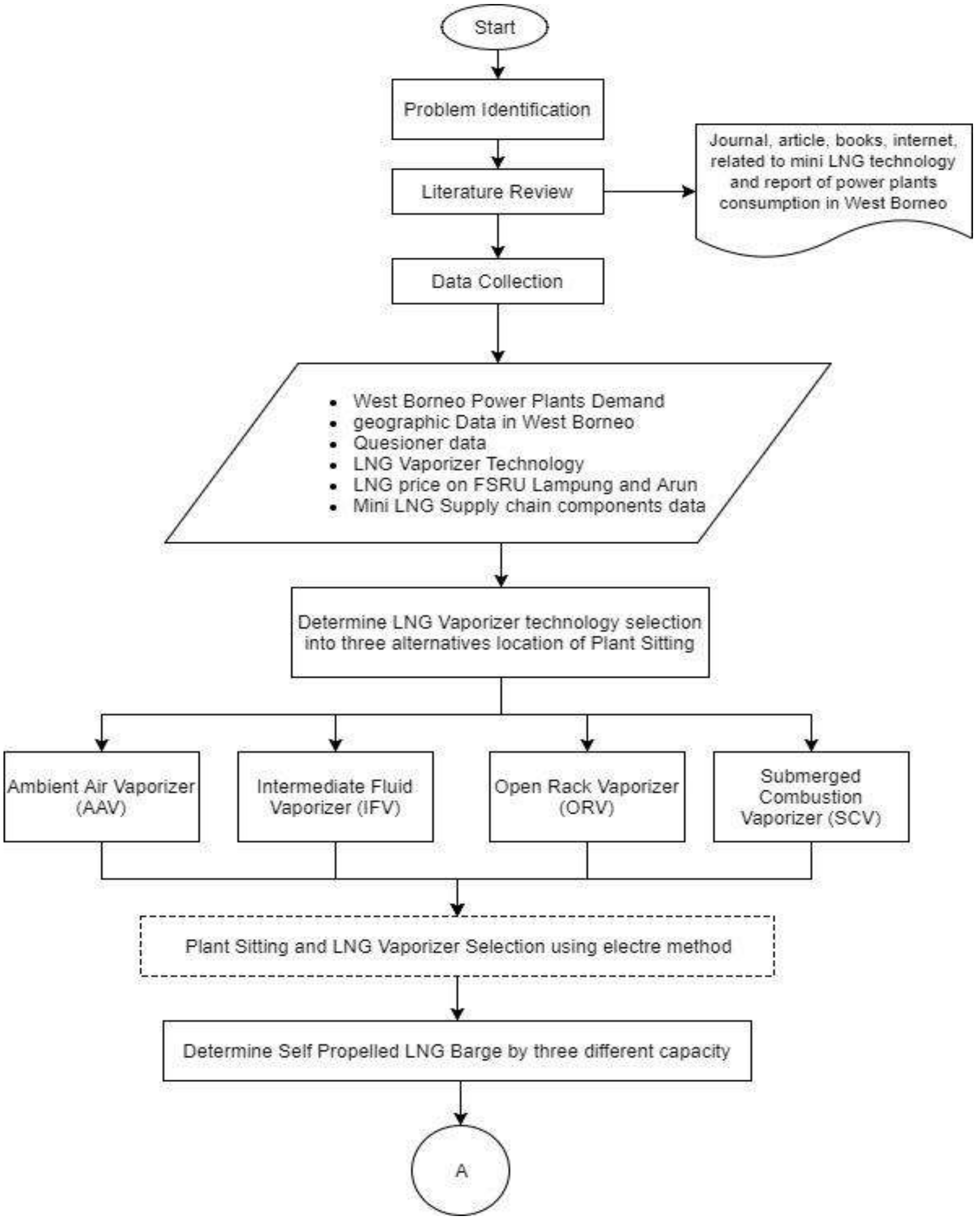


Figure.3.1 Flowchart Methodology

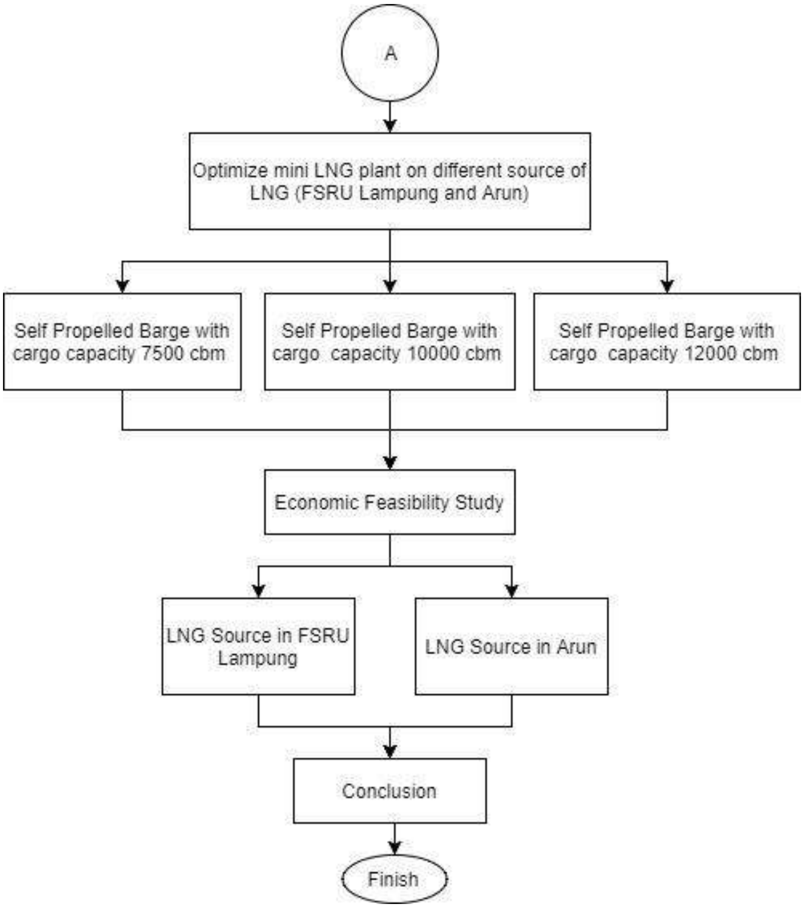


Figure.3.2 Flow Chart Methodology Continue

This research is done by structural process which is implemented as in the process flowchart. The sequence in this research is shown by topic conceptual design of mini LNG supply chain for power plants in West Borneo.

3.1 Problem Identification

The problem is identified by observation study in the *Rencana Operasional Tahunan (ROT) PLN Kalimantan Barat 2017,* finding information from journal & e-books in the internet, and reading statistics report from *RUPTL PLN 2016 - 2025*. In this research, the problem that will be analyzed is how to design the most optimal mini LNG supply chain and determine the conceptual design in terms of economic.

3.2 Literature Study

Literature Study is conducted to learn the material related to this research. On this sequence, related literature on the research topic include internet, books, journal, paper, report and project guide. Thus, literature study provides information data to solve the problem. In this research, literature study is related to Mini LNG supply chain components, Elimination and Choice Expressing Reality (Electre), LNG Technology, Linier Programming by using excel solver, and economic feasibilitythis research, the study literatures are related to the Mini LNG supply chain components, Elimination and choice expressing reality (Electre), LNG Technology, Linier Programming by using excel solver, and economic feasibility study.

3.3 Data Collection

Data collection is used as the object to analyze. In this research, there are several necessary data such as geographic data of location selection in Siantan, Pontianak. LNG Vaporizer technology, mini LNG supply chain components project guide. The data are collected from survey activity on the location for quality results or in the journal, books, paper, and internet for quantity results.

3.4 Plant Sitting Location & LNG Vaporizer Selection

Plant sitting sitting are located in West Borneo specifically at three location: Siantan Regency, Pontianak City, and Offshore (Mini FSRU). While LNG Vaporizer technology alternatives include Ambient Air Vaporizer (AAV), Open Rack Vaporizer (ORV), Intermediate Fluid Vaporizer (IFV), and Submerged Combustion Vaporizer (SCV). Data analysis will be conducted by Multi Criteria Decision Making (MCDM) using Electre Method. The process of decision making is to process the plant sitting location and LNG Vaporizer paralelly.

3.5 Optimization Self Propelled LNG Barge & LNG Storage Tank

Self-propelled LNG barge capacity alternatives are SPB LNG 7500 m^3, SPB LNG 10000 m^3, and SPB LNg 12000 m^3. While the storage tank alternatives are using LNG storage tank capacity of 100 m^3, 150 m^3, and 300 m^3. Data analysis is conducted by using linier programming (solver) to get output of capacity & number of asset and minimum investment.

3.6 Economic Feasibility Study

After Determining conceptual design for power plants in West Borneo, the next step is to determine the conceptual design in terms of economics. The source of LNG for power plants in West Borneo are FSRU Lampung and Arun Gas Refinery. A comparison will be done to determine which one has the most minimum and feasible investment.

3.7 Conclusion

Conclusion is the last sequence of the research. It must answer the problem identification. The conclusion is to design the most optimal mini LNG supply chain and calculate the conceptual design in terms of economics

CHAPTER IV
DATA ANALYSIS

This chapter provides the analyzed data based on problem statement in chapter I. In summary, there are three points that will be analyzed in this chapter, namely:

1. Selection of location for mini LNG plant in West Borneo and LNG Vaporizer technology by ELECTRE method.
2. Design Conceptual of mini LNG supply chain components by determining three Self Propelled LNG Barge to optimize capacity of LNG Storage tank, LNG vaporizer, LNG Pump, and other support components.
3. To analyze conceptual design in terms of economic feasibility study.

Regarding to the points, the sequence of data analyze is conducted as below:

4.1 Mini LNG Plant Location Selection

4.1.1 Alternative

Three alternatives of LNG location selection that will be evaluated include Siantan Recency, Pontianak City, Offshore (Mini FSRU). Table 4.2 below explains the subjective judgement to the attribute preferences accoding to the survey discussion, information, literature and engineering judgement explained below.

1. Alternative 1 – Siantan Regency
   Kabupaten Siantan is located in coordinate 0.0548460 S, 109.204387o which is located in north of Pontianak city. This regency consists of six villages and passed by Kapuas river with 6 meter depth.

Table 4.1 Disadvantages & Advantages Location in Siantan Regency

Siantan Regency	
Advantages	Disadvantages
Land and Preparation Cost	Future Business Development
Safety & Security	Berthing Facility
Dredging Cost is cheaper	Ease access for Material
Distance to Power Plants is good	Ease for Crew Access

Figure 4.1 Siantan Regency location plan

2. Alternative 2 – Pontianak City
   Pontianak located in the coordinate 0.0048220 S, 109.304926o E and has area about 107,82 km2. This city is in the south of Siantan Regency and passed by Kapuas river with 6 meter depth.

Table 4.2 Disadvantages & Advantages of location in Pontianak City

Pontianak City	
Advantages	Disadvantages
Future Business Development	Land and Preparation Cost
Berthing Facility	Dredging Cost
Ease access for Material	Permission Cost
Ease for Crew Access	Safety and Security

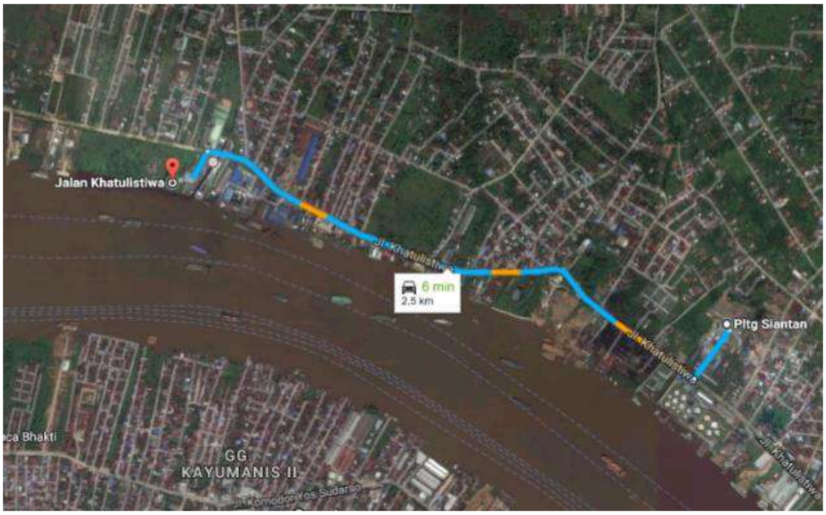


Figure 4.2 Pontianak City Location Plan

3. Alternative 3 – Mini FSRU (Offshore)
   Offshore facility for mini FSRU located in coordinate 0.072853 S, 108.965844o E in the china south sea and 18 km from PLTG MPP jungkat, Siantan.

Table 4.3 Disadvantages & Advantages location in Siantan Regency

Offshore (Mini FSRU)	
Advantages	Disadvantages
Future Business Development	Capital Cost
Safety & Security	Operational Cost
Permission Cost	Equipment Complexity
Period of Construction	Distance to Power Plants

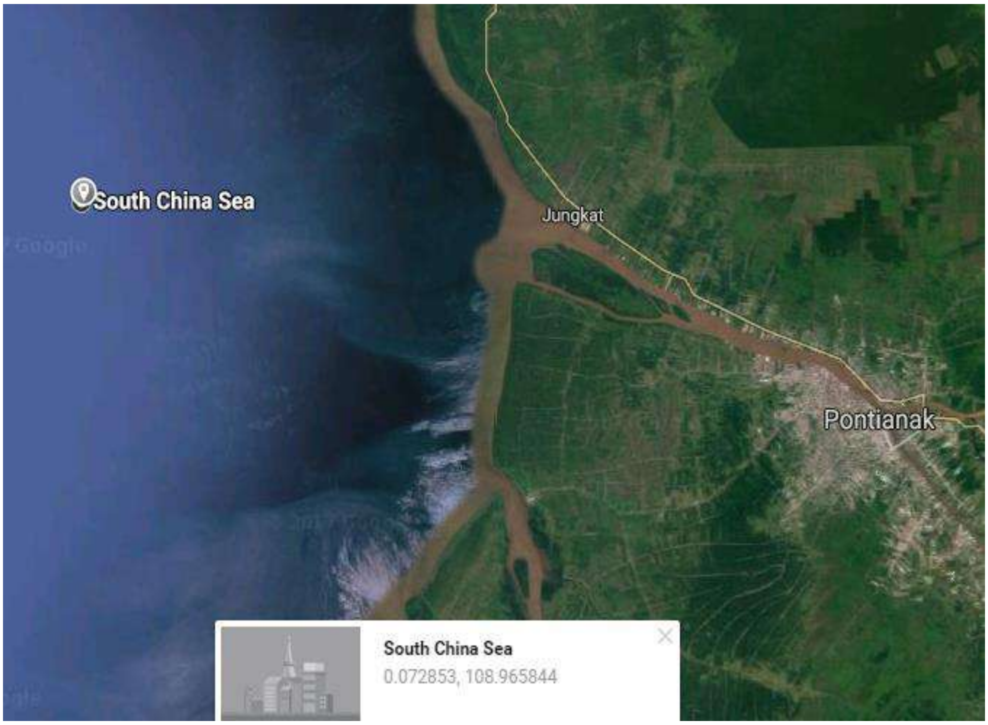


Figure 4.3 Offshore (Mini FSRU) location plan

Figure 4.4 Layout of Alternative location selection

4.1.2 Criteria

Criteria of plant sitting location selection is shown in table 4.4 below.

Table 4.4 Criteria of Location Selection

Mini LNG Plant Location Selection		
Economical	Environment	Technical
Land & Preparation Cost	Safety and Security	Period of Construction
Dredging Cost	Ease of Crew Access	Future Business Development
Berthing Facility	Ease of Material Access	Distance to Power Plant
Permission Cost		Equipment Complexity
Operational Cost		
Capital Cost		

Based on this table, it can be concluded that there are 13 criteria of mini LNG location selection which will be explain below:

1. Economical
a. Land and Preparation Cost

Land and preparation cost is the expenditure cost used to buy land in West Borneo for plant sitting. Every location in Pontianak and Siantan have different cost and different land availability.

b. Dredging Cost
Dredging cost is the expenditure cost used to dredge the land in the location. For building infrastucture of mini LNG plant and receiving terminal, it needs land with good structure, so land dredging and land dredging cost are needed.

c. Berthing Facility Cost
When LNG is unloaded by Self Propelled LNG barge, it needs berthing facility for operation, if a location has no berthing facility then it needs to be build and expenditure cost is required.

d. Permission Cost
If we build an infrastucture in Indonesia, it needs permission and accomodation cost, so permission cost is considered.

e. Capital Cost
Capital cost is only for Mini FSRU because if we need to build mini FSRU, it needs more materials.

f. Operational Cost
If infrastructure is operating in a location such as mini FSRU, then it needs operation cost for crew and tools as fuel oil, lubrication oil, operational for bunkering, etc.

2. Environmental

a. Safety and Security
Safety and security aspect is how good level of safety & security in a location, by comparing the three locations: Siantan Regency, Pontianak city and Offshore (Mini FSRU).

b. Ease of Crew Access
Ease of crew acces is how easy the crew or employee to access the mini LNG Infrastucture

c. Ease of Material Access
Ease of material access is how good the level of material access to build the mini LNG plant in a location.

3. Technical
a. Period of Construction
   Period of Costruction is how good is the level of construction in a location is needed, faster period construction of a location is better for a location to build mini LNG Plant Infrastructure.

b. Future Business Development
   Future business develoment is how good is the level of business development in a location in the future, better business development, then better investment in a location.

c. Distance to Power Plant
   Distance to Power Plant is how near the mini LNG Infrastructure to power plants. If mini LNG Infrastructure is close, then it can reduce cost for piping facility.

d. Equipment Complexity
   Equipment Complexity is how good equipment is installed in a location. Different equipment complexity occurs between offshore and onshore.

4.1.3 ELECTRE Implementation for Selection Plant Sitting Location

4.1.3.1 Validation Test

1. Validation Test
   Validation test has a function to determine if the questionnaire given to respondents is valid or not. By this formula

$$r_{hitung} = \frac{n.(\sum XY) - (\sum X).(\sum Y)}{\sqrt{[n.\sum X^2 - (\sum X)^2].[n.\sum Y^2 - (\sum Y)^2]}}$$

   The number of respondents must be 30 people. If r calculation > r number then the result is valid (H_o), if r calculation is lower than r number than the result is not valid (H_a). r $tabel_n$ with n = 30, the number of r number is 0,361. In this validation process, all the questionnaire responds are valid. (See Attachment C).

4.1.3.2 Preference and Weight Data

After determining the alternatives and criterias of location selection, in ELECTRE implementation method every single criteria needs should be given preference and weight by respondents/expert using Likert scale. Likert scale

(Table 4.5) for preference value is scaled from 1 to 5. The higher value indicates very good quality in that criteria

Table 4.5 Value of Likert Scale in Preference

Likert Scale	Value
1	Very Bad
2	Bad
3	Normal
4	Good
5	Very Good

While for weighting value is also using likert scale (Table 4.6) which value given is higher then weighter the weight in that criteria.

Table 4.6 Value of likert Scale in Weight

Likert Scale	Value
1	Less important
3	Medium important
5	Important
7	Very Important
9	Absolutely Important
2,4,6,8	Middle Value from each likert scale

The media used for this research is questionnaire which distributed to thirty experts randomly. Each expert will answer the question based on their analysis in every question needed. The preference and weight value is concluded using mode. Mode is number which can be supplied as numbers, ranges, named ranges, or cell references that contain numeric values frequently. The result of preference and weight value is shown in table 4.7 below.

Table 4.7 Preference of Criteria Value of Location Selection

Criteria	Alternative			Weight
	Siantan Regency	Pontianak City	Offshore (Mini FSRU)	
Land and Preparation cost	4,00	2,00	5,00	7
Dredging Cost	3,00	3,00	5,00	7
Operational Cost	4,00	3,00	5,00	9
Capital Cost	4,00	4,00	2,00	7
Berthing Facility	4,00	3,00	5,00	7
Permission Cost	3,00	4,00	4,00	7
Safety and Security	4,00	3,00	5,00	9
Access for Distribution	4,00	4,00	4,00	9
Access for crew	3,00	4,00	3,00	7
Future business development	4,00	5,00	4,00	9
Periode of Construction	4,00	4,00	3,00	7
Distance to Power Plant	4,00	3,00	3,00	7
Equipment complexity	4,00	4,00	2,00	5

4.1.3.3 Data Analysis

1. **Step 1: Normalize**

In Electre Method, Normalize has function to generalize all criteria to become same value. In case, if the criteria is put the price of capital cost or distance, it could be generalized with the same value with quality criterias.

$$\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \text{ for i = 1,2,3,.... m and j = 1,2,3... n}$$

By using this formula of normalize, it can be concluded the value of each criteria which is shown in table 4.8 below.

Table 4. 8 Value of Normalize of Location Selection

Criteria	Alternative		
	Siantan Regency	Pontianak City	Offshore (Mini FSRU)
Land and Preparation cost	0,59628	0,29814	0,74536
Dredging Cost	0,44721	0,44721	0,74536
Operational Cost	0,59628	0,44721	0,74536
Capital Cost	0,596284	0,59628	0,29814
Berthing Facility	0,59628	0,44721	0,74536
Permission Cost	0,44721	0,59628	0,59628
Safety and Security	0,59628	0,44721	0,74536
Access for Distribution	0,59628	0,59628	0,59628
Access for crew	0,44721	0,59628	0,44721
Future Business Development	0,59628	0,74536	0,59628
Period of Construction	0,59628	0,59628	0,44721
Distance to Power Plant	0,59628	0,44721	0,44721
Equipment complexity	0,59628	0,59628	0,29814

2. Step 2: Weighting Matriks Normalize

Once normalized, each column of the matrix R multiplied by the weights (wj). Thus, the weighted normalized matrix is V = W.R written as:

$$V = R \times W$$

$$\begin{matrix} v_{11} & v_{12} & v_{1n} \\ v_{21} & v_{22} & v_{2n} \\ v_{m1} & v_{m2} & v_{mn} \end{matrix} = \begin{matrix} w_1 r_{11} & w_2 r_{12} & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & w_n r_{2n} \\ w_1 r_{m1} & w_2 r_{m2} & w_n r_{mn} \end{matrix}$$

By using this formula it can be summarized the value in table 4.9 below.

Table 4.9 Weight Matriks Normalize Value

Criteria	Alternative		
	Siantan Regency	Pontianak City	Offshore (Mini FSRU)
Land and Preparation cost	4,17399	2,08700	5,21749
Dredging Cost	3,13050	3,13050	5,21749
Operational Cost	5,36656	4,02492	6,70820
Capital Cost	4,17399	4,17399	2,08700
Berthing Facility	4,17399	3,13050	5,21749
Permission Cost	3,13050	4,17399	4,17399
Safety and Security	5,36656	4,02492	6,70820
Access for Distribution	5,36656	5,36656	5,36656
Access for crew	3,13050	4,17399	3,13050
Future business development	5,36656	6,70820	5,36656
Periode of Construction	4,17399	4,17399	3,13050
Distance to Power Plant	4,17399	3,13050	3,13050
Equipment complexity	2,98142	2,98142	1,49071

Based on this value we can calculate the value of difference absolute which is shown in the table 4.10 below.

Table 4.10 Value of Difference Absolute

Criteria	Absolute Difference		
	Siantan – Pontianak	Pontianak City	Siantan – Pontianak
Land and Preparation cost	2,08700	1,04350	3,13050
Dredging Cost	0,00000	2,08700	2,08700
Operational Cost	1,34164	1,34164	2,68328
Capital Cost	0,00000	2,08700	2,08700
Berthing Facility	1,04350	1,04350	2,08700
Permission Cost	1,04350	1,04350	0,00000
Safety and Security	1,34164	1,34164	2,68328
Access for Distribution	0,00000	0,00000	0,00000

Table 4.10 Value of Different Absolute (continued)

Access for crew	1,04350	0,00000	1,04350
Future business development	1,34164	0,00000	1,34164
Periode of Construction	0,00000	1,04350	1,04350
Distance to Power Plant	1,04350	1,04350	0,00000
Equipment complexity	0,00000	1,49071	1,49071

3. Step 3: Set of Concordances and Discordances

For each pair of alternatives k and l (k, l = 1,2,3, ..., m and k ≠ l) A set of criteria is divided into two subsets, namely concordance and discordance. Alternative criteria is included as concordance if C_{kl} ={j, v_{kl} >= v_{ij} } for j = 1,2,3,.....n. Instead, complementary subsets of concordance are set discordance, namely when D_{kl} ={j, v_{kl} < v_{ij} } for j = 1,2,3,.....n. By Using this formula, it the value of concordances and discordances can be summarized in Table 4.10 below.

Table 4.11 Concordances and Disordances a_1 to a_2

Criteria	a_1 to a_2		a_2 to a_1	
	Concor dances	Discor dances	Concor dances	Discor dances
Land and Preparation cost	7,00	0,00	0,00	2,08
Dredging Cost	7,00	0,00	7,00	0,00
Operational Cost	9,00	0,00	0,00	1,34
Capital Cost	7,00	0,00	7,00	0,00
Berthing Facility	7,00	0,00	0,00	1,04
Permission Cost	0,00	1,04	7,00	0,00
Safety and Security	9,00	0,00	0,00	1,34
Access for Distribution	9,00	0,00	9,00	0,00
Access for crew	0,00	1,04	7,00	0,00
Future business development	0,00	1,34	9,00	0,00
Periode of Construction	7,00	0,00	7,00	0,00
Distance to Power Plant	7,00	0,00	0,00	1,04
Equipment Complexity	5,00	0,00	5,00	0,00

Table 4.12 below shows value of concordances and discordances value of a_1 to a_3 and a_3 to a_1.

Table 4.12 Concordances and Disordances a_1 to a_3

Criteria	a_1 to a_3		a_3 to a_1	
	Concor dances	Discor dances	Concor dances	Discor dances
Land and Preparation Cost	0,00	1,04	7,00	0,00
Dredging Cost	0,00	2,09	7,00	0,00
Operational Cost	0,00	1,34	9,00	0,00
Capital Cost	7,00	0,00	0,00	2,09
Berthing Facility	0,00	1,04	7,00	0,00
Permission Cost	0,00	1,04	7,00	0,00
Safety and Security	0,00	1,34	9,00	0,00
Access for Distribution	9,00	0,00	9,00	0,00
Access for crew	7,00	0,00	7,00	0,00
Future business development	9,00	0,00	9,00	0,00
Periode of Construction	7,00	0,00	0,00	1,04
Distance to Power Plant	7,00	0,00	0,00	1,04
Equipment Complexity	5,00	0,00	0,00	1,49

Table 4.12 below shows value of concordances and discordances value of a_1 to a_3 and a_3 to a_1.

Table 4.13 Concordances and Disordances a_2 to a_3

Criteria	a_2 to a_3		a_3 to a_2	
	Concor dances	Discor dances	Concor dances	Discor dances
Land and Preparation cost	0,00	3,13	7,00	0,00
Dredging Cost	0,00	2,09	7,00	0,00

Table 4.13 Concordances and Disordances a_2 to a_3 (continued)

Operational Cost	0,00	2,68	9,00	0,00
Capital Cost	7,00	0,00	0,00	2,09
Berthing Facility	0,00	2,09	7,00	0,00
Permission Cost	7,00	0,00	7,00	0,00
Safety and Security	0,00	2,68	9,00	0,00
Access for Distribution	9,00	0,00	9,00	0,00
Access for crew	7,00	0,00	0,00	1,04
Future business development	9,00	0,00	0,00	1,34
Periode of Construction	7,00	0,00	0,00	1,04
Distance to Power Plant	7,00	0,00	7,00	0,00
Equipment Complexity	5,00	0,00	0,00	1,49

4. Step 4: Calculate Matriks Concordances and Disordances

a. Calculating the matrix concordance

To determine the value of the elements in the matrix concordance is by adding weights included in the set of concordances, written in mathematical formula as follows:

$$C_{kl} = \sum_{je} C_{kl}$$

By using this formula, it all matrix in corcordance can be summarized, so the result is shown in Table 4.13 below.

Table 4.14 Matriks Concordance Calculate

Matriks Concordances Calculate			
	Alt 1	Alt 2	Alt 3
Alt 1	0,000	58,000	71,000
Alt 2	74,000	0,000	62,000
Alt 3	51,000	58,000	0,000

b. Calculating the matrix discordances

To determine the value of elements in matrix discordances is by dividing the maximum difference of criteria that included into subsets discordances with a maximum difference of the value of all the criteria; mathematically written as follows:

$$d_{kl} = \frac{\max\{|v_{kj} - v_{ij}|\}}{\max\{|v_{kj} - v_{ij}|\}}$$

Table 4.15 Matriks Discordances Calculate

Matriks Discordances Calculate			
	Alt 1	Alt 2	Alt 3
Alt 1	0,000	1,000	1,000
Alt 2	0,643	0,000	0,667
Alt 3	1,000	1,000	0,000

5. Step 5: Determine Dominant Matriks Concordances and Discordances

a. Calculating the dominant matrix concordance

Matrix F as the dominant matrix concordance can be built with the help of threshold value, by comparing the value of each matrix element concordance with the threshold value.

$$C_{kl} >= C$$

with a threshold value (c) are:

$$c = \frac{\sum_{k=1}^{m}\sum_{i=1}^{m} c_{kl}}{m\,(m-1\,)}$$

so, the elements of the matrix F are determined as follow:

$$f_{kl} = \{\frac{1, if\ c_{kl} \geq c}{0, if\ c_{kl} < c}$$

Threshold Concordances = 62,33

Table 4.16 Matriks Concordances Threshold

Matriks Concordances Threshold			
	Alt 1	Alt 2	Alt 3
Alt 1	0,00	0,00	1,00
Alt 2	1,00	0,00	1,00
Alt 3	0,00	0,00	0,00

b. Calculating the dominant matrix discordances

Matrix G as the dominant matrix can be built with the help discordance threshold value:

$$d = \frac{\sum_{k=1}^{m}\sum_{i=1}^{m} d_{kl}}{m\,(m-1)}$$

and elements of the matrix G is determined as follows:

$$g_{kl} = \{\frac{1, if\ d_{kl} \geq c}{0, if\ d_{kl} < c}$$

Threshold Discordances = 0,884

Table 4.17 Matriks Discordances Threshold

Matriks Discordances Threshold			
	Alt 1	Alt 2	Alt 3
Alt 1	0,00	1,00	1,00
Alt 2	0,00	0,00	0,00
Alt 3	1,00	1,00	0,00

6. **Step 6: Determine aggregate dominance matrix**
   Matrix E as the aggregate dominance matrix is a matrix which each element is the multiplication between matrix element F with the corresponding elements of matrix G, mathematically expressed as:

$$E_{kl} = f_{kl} \times g_{kl}$$

Table 4.18 Agregate Matriks Dominance

Agregate Matriks Dominance			
	Alt 1	Alt 2	Alt 3
Alt 1	0,00	0,00	1,00
Alt 2	0,00	0,00	0,00
Alt 3	0,00	0,00	0,00

7. **Step 7: Elimination less favorable alternative**
   The matrix E gives the preferred order of each alternative if the alternative AK is a better alternative than Al. Thus, the line in matrix E which has the least number can be eliminated. Thus, the best alternative is the one that dominates the others. Based on that table, alternative 2 and 3 is less favourable alternative and it should be eliminated, so the alternative 1 is the best alternative for LNG plant sitting location. Alternative 1 is Siantan Regency.

Table 4.19 Elimination alternative

Alternative	Value
Alternative 1	1,00
Alternative 2	0,00
Alternative 3	0,00

4.2 LNG Vaporizer Selection
4.2.1 Alternative

1. **Ambient Air Vaporizer (AAV)**
   Technology AAV is using ambiet air as a source of heat-to-heat transfer LNG. This performance depends on temperature, altitude, humidity, and location.

Table 4.20 Ambient Air Vaporizer Advantages and Disadvantages

Ambient Air Vaporizer	
Advantages	Disadvantages
Ease of Operational	Environmental Factor
Maintenance Cost	Proven Technology
Pollution	Fluctuation Load
Period of Construction	Safety Operation

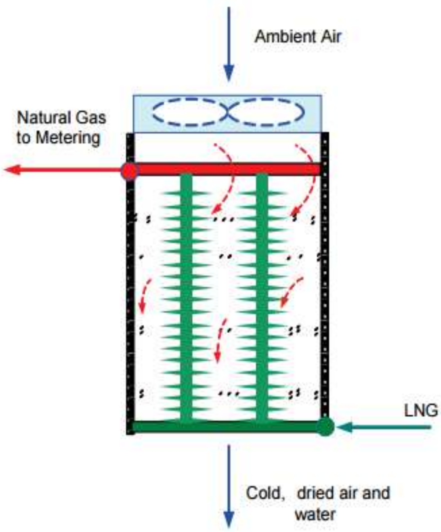


Figure 4.5 Ambient Air Vaporizer
(Patel, 2013)

2. **Intermediate Fluid Vaporizer - Glycol Water (IFV)**
   Intermediate Fluid Vaporizer using glycol water as a media heat transfer. Glycol water has very low freezing point thus freezing does not occured when being operated with LNG. This technology also has good efficiency but has complex equipment.

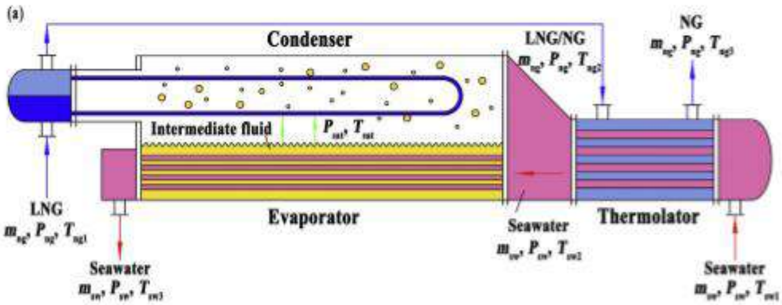


Figure 4.6 Intermediate Fluid Vaporizer
(Patel, 2013)

Table 4.21 Glycol Water IFV Advantages and Disadvantages

Glycol Water Intermediate Fluid Vaporizer	
Advantages	Disadvantages
Safety Operation	Proven Technology
Maintenance Cost	Availability of Heat Source
Pollution	Equipment Complexity
Ease of Maintenance	Operational Cost

3. **Open Rack Vaporizer (ORV)**
   Open rack vaporizer using sea water as a media of heat transfer. This technology is simple but need more sea water with good quality.

Table 4.22 Open Rack Vaporizer Advantages and Disadvantages

Open Rack Vaporizer	
Advantages	Disadvantages
Proven Technology	Maintenance Cost
Equipment Complexity	Ease of Maintenance
Pollution	Geographic Area
Availability of Spare Part	Ease of Operational

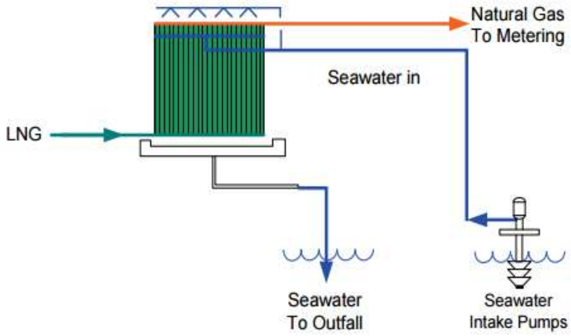


Figure 4.7 Open Rack Vaporizer
(Patel, 2013)

4. **Submerged Combustion Vaporizer (SCV)**
   Submerged Combustion Vaporizer using water bath which is heated with hot flue gas to imitate the freezing. This technology has a good record safety but exhaust some emmission.

Table 4.23 Submerged Combustion Vaporizer Advantages and Disadvantages

Submerged Combustion Vaporizer	
Advantages	**Disadvantages**
Proven Technology	Pollution
Safety Operation	Equipment Complexibility
Environmental Factor	Operational Cost
Fluctuation Load	Capital Cost

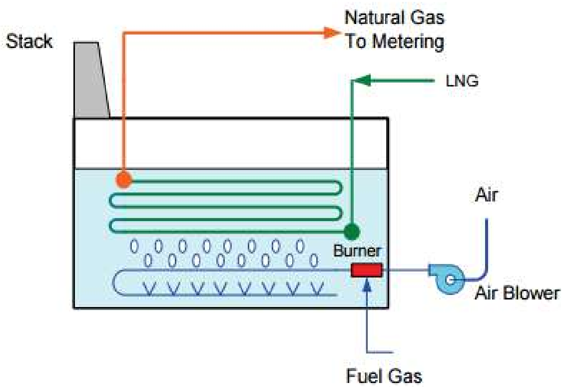


Figure 4.8 Submerged Combustion Vaporizer
(Patel, 2013)

4.2.2 Criteria

The criteria of LNG Vaporizer is shown in table 4.25 below.

Table 4.24 LNG Vaporizer Criteria

LNG Vaporizer			
Economical	Technical	Environmental	Operational
Capital Cost	Availability of Heat Source	Geographic Area	Ease of Operational
Operational Cost	Availability of Spare part	Environmental Factor	Ease of Maintenance
Maintenance Cost	Proven Technology	Pollution	Safety Operation
	Fluctuation of Load		
	Equipment Complexibility		

Based on on this table, it can be concluded that there are 13 criteria of LNG Vaporizer selection which will be explained below:

1. Economical

a. Capital Cost
Capital cost is expenditure cost used for expending general asset and support asset.

b. Operasional Cost
Operational Cost is expenditure cost used for operating the asset and support asset.

c. Maintenance Cost
Maintenance Asset is expenditure cost used for maintaining the asset to prevent failure.

2. Technical

a. Availability of Heat Source
Level of Heat source of LNG Vaporizer available in Indonesia.

b. Availability of Spare Part
Level of Spare part of LNG Vaporizer available in Indonesia.

c. Fluctuation Load
The ability of LNG vaporizer in some differents load in accordance with power plants.

d. Equipment Complexity
The level of components simplicity of LNG Vaporizer.

e. Proven Technology
How LNG Vaporizer is proven in Indonesia.

3. Environmental

a. Pollution
The level of Pollution exhausted by LNG vaporizer Technology.

b. Geographic Area
LNG Vaporizer compatibility to the geographical aspect of West Borneo.

c. Environmental Factor
LNG Vaporizer compatibility to the environmental factor in West Borneo such as temperature, wind, humidity etc.

4. Operational

a. Ease of Operational
How ease the LNG Vaporizer is operated by the operator during operation time.

b. Ease of Maintenance
How ease the LNG Vaporizer is maintained during failure time.

c. Safety Operation
The level of safety LNG Vaporizer during operation.

4.2.3 ELECTRE Implementation for Selection LNG Vaporizer

4.2.3.1 Validation Test

1. Validation Test
Validation test functions to determine if the questionnaire given to respondents is valid or not. By this formula

$$r_{hitung} = \frac{n.(\sum XY) - (\sum X).(\sum Y)}{\sqrt{[n.\sum X^2 - (\sum X)^2].[n.\sum Y^2 - (\sum Y)^2]}}$$

The number of respondents must be 30 people. If r calculation > r number then the result is valid (H_o), if r calculation is lower than r number then the result is not valid (H_a). r $tabel_n$ with n = 30, the number of r number is 0,361. In this validation process, all the questionnaire responds are valid. (See Attachment C).

4.2.3.2 Preference and Weight Data

After determining the alternatives and criterias of LNG Vaporizer selection, in Electre implementation method, every single criteria needs to be given preference and weight by respondents/experts using Likert scale. Likert scale (Table 4.25) for preference value has the scale of 1-5. The higher indicates very good quality in that criteria.

Table 4.25 Value of Likert Scale in Preference

Likert Scale	Value
1	Very Bad
2	Bad
3	Normal
4	Good
5	Very Good

While Likert scale is also used for weighting value (Table 4.26) in which higher value will increase the weight in that criteria.

Table 4.26 Value of likert Scale in Weight

Likert Scale	Value
1	Less important
3	Medium important
5	Important
7	Very Important
9	Absolutely Important
2,4,6,8	Middle Value from each likert scale

The media used for this is questionnarie shared to thirty experts randomly. Each expert will answer the question based on their analysis of each question. The preference and weight value is concluded by using mode. Mode is number which can be supplied as numbers, ranges, named ranges, or cell references that contain numeric values frequently. The result of preference and weight value is shown in table 4.28 below.

Table 4.27 Preference and Weight

Criteria	Alternative				Weight
	AAV	IFV	ORV	SCV	
Capital Cost	3,00	3,00	4,00	3,00	7,00
Operational Cost	4,00	3,00	4,00	3,00	8,00
Maintenance Cost	4,00	3,00	3,00	3,00	8,00
Proven Technology	3,00	4,00	4,00	4,00	7,00
Availability of Heat Source	4,00	3,00	4,00	4,00	7,00
Availability of Spare Part	3,00	3,00	3,00	3,00	8,00
Fluctuation Load	3,00	4,00	3,00	4,00	7,00
Equipment complexity	4,00	3,00	3,00	3,00	6,00
Environmental Factor	4,00	4,00	5,00	3,00	7,00
Geographic Area	4,00	3,00	4,00	3,00	7,00
Pollution	4,00	3,00	4,00	3,00	7,00
Ease of Operational	4,00	3,00	4,00	3,00	7,00
Ease of Maintenance	4,00	3,00	3,00	3,00	7,00
Safety Operation	4,00	3,00	4,00	4,00	9,00

4.2.3.3 Data Analysis

1. **Step 1: Normalize**

   In Electre Method, Normalize has function to generalize all criteria become same value. In case, if the criteria is put the price of Capital cost or distance, it could be generalize with the same value with quality criterias.

   $$\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \text{ for i = 1,2,3,.... m and j = 1,2,3... n}$$

By using this formula of normalize, it can be concluded the value of each criteria which is shown in table 4.28 below.

Table 4.28 Value of Normalize of LNG Vaporizer

Criteria	Alternative			
	AAV	IFV	ORV	SCV
Capital Cost	3,6015	3,6015	4,8020	3,6015
Operational Cost	4,9976	3,7482	4,9976	3,7482
Maintenance Cost	4,8020	3,6015	3,6015	3,6015
Proven Technology	2,3426	3,1235	3,1235	3,1235
Availability of Heat Source	3,4300	2,5725	2,5725	3,4300
Availability of Spare Part	4,6188	4,6188	4,6188	4,6188
Fluctuation Load	3,6015	4,8020	3,6015	3,6015
Equipment complexity	4,1160	3,0870	3,0870	3,0870
EnvironmentalFactor	1,9052	4,7629	4,7629	2,8577
Geographic Area	4,3729	3,2796	4,3729	3,2796
Pollution	3,8125	2,2875	2,2875	0,7625
Ease of Operational	4,3729	3,2796	4,3729	3,2796
Ease of Maintenance	4,0415	4,0415	4,0415	2,6943
Safety Operation	6,1739	4,6305	4,6305	4,6305

2. **Step 2: Weighting Matriks Normalize**
   Once normalized, each column of the matrix R multiplied by the weights (wj). Thus, the weighted normalized matrix is V = W.R written as:

$$V = R \times W$$

$$\begin{matrix} v_{11} & v_{12} & v_{1n} \\ v_{21} & v_{22} & v_{2n} \\ v_{m1} & v_{m2} & v_{mn} \end{matrix} = \begin{matrix} w_1 r_{11} & w_2 r_{12} & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & w_n r_{2n} \\ w_1 r_{m1} & w_2 r_{m2} & w_n r_{mn} \end{matrix}$$

By using this formula it can be summarized the value in table 4.29.

Table 4.29 Weight Matriks Normalize Value

Criteria	Alternative			
	AAV	IFV	ORV	SCV
Capital Cost	3,6015	3,6015	4,8020	3,6015
Operational Cost	4,9976	3,7482	4,9976	3,7482
Maintenance Cost	4,8020	3,6015	3,6015	3,6015
Proven Technology	2,3426	3,1235	3,1235	3,1235
Availability of Heat Source	3,4300	2,5725	2,5725	3,4300
Availability of Spare Part	4,6188	4,6188	4,6188	4,6188
Fluctuation Load	3,6015	4,8020	3,6015	3,6015
Equipment complexity	4,1160	3,0870	3,0870	3,0870
EnvironmentalFactor	1,9052	4,7629	4,7629	2,8577
Geographic Area	4,3729	3,2796	4,3729	3,2796
Pollution	3,8125	2,2875	2,2875	0,7625
Ease of Operational	4,3729	3,2796	4,3729	3,2796
Ease of Maintenance	4,0415	4,0415	4,0415	2,6943
Safety Operation	6,1739	4,6305	4,6305	4,6305

Table 4.30 Absolute Different

Table 4.30 below shows value of absolute different for each criteria.

Criteria	Absolute Difference					
	A1-A2	A1-A3	A1-A4	A2-A3	A2-A4	A3-A4
Capital Cost	0,000	1,200	0,000	1,200	0,000	1,200
Operational Cost	1,249	0,000	1,249	1,249	0,000	1,249
Maintenance Cost	1,200	1,200	1,200	0,000	0,000	0,000
Proven Technology	1,090	1,090	0,781	0,000	0,000	0,000
Availability of Heat Source	1,090	0,000	1,090	1,090	1,090	0,000
Availability of Spare Part	0,000	0,000	0,000	0,000	0,000	0,000

Table 4.30 Absolute Different (continued)

Fluctuation Load	1,200	0,000	0,000	1,200	0,000	1,200
Equipment complexity	1,029	1,029	1,029	0,000	0,000	0,000
EnvironmentalFactor	0,000	0,930	1,030	0,930	0,930	1,850
Geographic Area	1,093	0,000	1,090	1,093	0,000	1,090
Pollution	1,090	0,000	1,090	1,093	0,000	1,090
Ease of Operational	1,090	0,000	1,090	1,093	0,000	1,090
Ease of Maintenance	1,200	1,200	1,200	0,000	0,000	0,000
Safety Operation	1,410	0,000	0,000	1,41	1,410	0,000

3. **Step 3: Set of Concordances and Discordances**
   For each pair of alternatives k and l (k, l = 1,2,3, ..., m and k ≠ l) A set of criteria is divided into two subsets, namely concordance and discordance. Alternative criteria in including concordance if: C_{kl} ={j, v_{kl} >= v_{ij} } for j = 1,2,3,.....n. Instead, complementary subsets of concordance are set discordance, namely when: D_{kl} ={j, v_{kl} < v_{ij} } for j = 1,2,3,.....n. By Using this Formula it can be summarized the value of concordances and discordances in table 4.31 below.

Table 4.31 Concordances and Discordances Value a_1 to a_2 and a_2 to a_1

Criteria	a_1 to a_2		a_2 to a_1	
	Concordances	Discordances	Concordances	Discordances
Capital Cost	7,000	0,000	7,000	0,000
Operational Cost	8,000	0,000	0,000	1,249
Maintenance Cost	7,000	0,000	0,000	1,200
Proven Technology	0,000	1,093	7,000	0,000
Availability of Heat Source	7,000	0,000	0,000	1,093
Availability of Spare Part	8,000	0,000	8,000	0,000
Fluctuation Load	0,000	1,200	7,000	0,000
Equipment complexity	6,000	0,000	0,000	1,029
Environmental Factor	7,000	0,000	7,000	0,000
Geographic Area	7,000	0,000	0,000	1,093
Pollution	7,000	0,000	0,000	1,093
Ease of Operational	7,000	0,000	0,000	1,093
Ease of Maintenance	7,000	0,000	0,000	1,200
Safety Operation	0,000	0,000	0,000	1,406

Table 4.32 below shows value of concordances and discordances value of a_1 to a_3 and a_3 to a_1.

Table 4.32 Concordances and Discordances Value a_1 to a_3 and a_3 to a_1

Criteria	a_1 to a_3		a_3 to a_1	
	Concor dances	Discor dances	Concor dances	Discor dances
Capital Cost	0,000	1,200	7,000	0,000
Operational Cost	8,000	0,000	8,000	0,000
Maintenance Cost	7,000	0,000	0,000	1,200
Proven Technology	0,000	1,093	7,000	0,000
Availability of Heat Source	7,000	0,000	7,000	0,000
Availability of Spare Part	8,000	0,000	8,000	0,000
Fluctuation Load	7,000	0,000	7,000	0,000
Equipment complexity	6,000	0,000	0,000	1,029
EnvironmentalFactor	0,000	0,927	7,000	0,000
Geographic Area	7,000	0,000	7,000	0,000
Pollution	7,000	0,000	7,000	0,000
Ease of Operational	7,000	0,000	7,000	0,000
Ease of Maintenance	7,000	0,000	0,000	1,200
Safety Operation	0,000	0,000	9,000	0,000

Table 4.33 below shows value of concordances and discordances value of a_1 to a_4 and a_4 to a_1.

Table 4.33 Concordances and Discordances Value a_1 to $a_4$and a_4 to a_1

Criteria	a_1 to a_4		a_4 to a_1	
	Concor dances	Discor dances	Concor dances	Discor dances
Capital Cost	7,000	0,000	7,000	0,000
Operational Cost	8,000	0,000	0,000	1,249
Maintenance Cost	7,000	0,000	0,000	1,200
Proven Technology	0,000	1,093	7,000	0,000
Availability of Heat Source	7,000	0,000	7,000	0,000

Table 4.33 Concordances and Discordances Value a_1 to $a_4$and a_4 to a_1 (continued)

Availability of Spare Part	8,000	0,000	8,000	0,000
Fluctuation Load	0,000	1,200	7,000	0,000
Equipment complexity	6,000	0,000	0,000	1,029
EnvironmentalFactor	7,000	0,000	0,000	0,927
Geographic Area	7,000	0,000	0,000	1,093
Pollution	7,000	0,000	0,000	1,093
Ease of Operational	7,000	0,000	0,000	1,093
Ease of Maintenance	7,000	0,000	0,000	1,200
Safety Operation	0,000	0,000	9,000	0,000

Table 4.33 below shows value of concordances and discordances value of a_2 to a_3 and a_3 to a_2.

Table 4.34 Concordances and Discordances Value a_2 to a_3 and a_3 to a_3

Criteria	a_2 to a_3		a_3 to a_3	
	Concor dances	Discor dances	Concor dances	Discor dances
Capital Cost	0,000	1,200	7,000	0,000
Operational Cost	0,000	1,249	8,000	0,000
Maintenance Cost	7,000	0,000	7,000	0,000
Proven Technology	7,000	0,000	7,000	0,000
Availability of Heat Source	0,000	1,093	7,000	0,000
Availability of Spare Part	8,000	0,000	8,000	0,000
Fluctuation Load	7,000	0,000	0,000	1,200
Equipment complexity	6,000	0,000	6,000	0,000
EnvironmentalFactor	0,000	0,927	7,000	0,000
Geographic Area	0,000	1,093	7,000	0,000
Pollution	0,000	1,093	7,000	0,000
Ease of Operational	0,000	1,093	7,000	0,000
Ease of Maintenance	7,000	0,000	7,000	0,000
Safety Operation	0,000	0,000	9,000	0,000

Table 4.33 below shows value of concordances and discordances value of a_2 to a_4 and a_4 to a_2.

Table 4.35 Concordances and Discordances Value a_2 to $a_4$and a_4 to a_2

Criteria	a_2 to a_4		a_4 to a_2	
	Concor dances	Discor dances	Concor dances	Discor dances
Capital Cost	7,000	0,000	7,000	0,000
Operational Cost	8,000	0,000	8,000	0,000
Maintenance Cost	7,000	0,000	7,000	0,000
Proven Technology	7,000	0,000	7,000	0,000
Availability of Heat Source	0,000	1,093	7,000	0,000
Availability of Spare Part	8,000	0,000	8,000	0,000
Fluctuation Load	7,000	0,000	7,000	0,000
Equipment complexity	6,000	0,000	6,000	0,000
EnvironmentalFactor	7,000	0,000	0,000	0,927
Geographic Area	7,000	0,000	7,000	0,000
Pollution	7,000	0,000	7,000	0,000
Ease of Operational	7,000	0,000	7,000	0,000
Ease of Maintenance	7,000	0,000	7,000	0,000
Safety Operation	0,000	0,000	9,000	0,000

Table 4.33 below shows value of concordances and discordances value of a_3 to a_4 and a_4 to a_3.

Table 4.36 Concordances and Discordances Value a_3 to a_4 and a_4 to a_3

Criteria	a_3 to a_4		a_4 to a_3	
	Concor dances	Discor dances	Concor dances	Discor dances
Capital Cost	7,000	0,000	0,000	1,200
Operational Cost	8,000	0,000	0,000	1,249
Maintenance Cost	7,000	0,000	7,000	0,000
Proven Technology	7,000	0,000	7,000	0,000
Availability of Heat Source	7,000	0,000	7,000	0,000
Availability of Spare Part	8,000	0,000	8,000	0,000
Fluctuation Load	0,000	1,200	7,000	0,000
Equipment complexity	6,000	0,000	6,000	0,000

Table 4.36 Concordances and Discordances Value a_3 to a_4 and a_4 to a_3 (continued)

EnvironmentalFactor	7,000	0,000	0,000	1,854
Geographic Area	7,000	0,000	0,000	1,093
Pollution	7,000	0,000	0,000	1,093
Ease of Operational	7,000	0,000	0,000	1,093
Ease of Maintenance	7,000	0,000	7,000	0,000
Safety Operation	0,000	0,000	9,000	0,000

4. **Step 4: Calculate Matriks Concordances and Discordances**

a. Calculating the matrix concordance

To determine the value of the elements in the matrix concordance is by adding weights are included in the set of concordances, is mathematical is as follows:

$$C_{kl} = \sum_{je} C_{kl}$$

By using this formula, it can be summarized all matriks in corcordance, so the result is shown in table 4.37 below.

Table 4.37 Matrix Concordances and Discordances

Matriks Concordances				
	Alt 1	Alt 2	Alt 3	Alt 4
Alternative 1	0,00	36,00	81,00	45,00
Alternative 2	87,00	0	85,00	94,00
Alternative 3	80,00	42,00	0	58,00
Alternative 4	87,00	85,00	94,00	0

b. Calculating the matrix discordances

To determine the value of elements in the matrix discordances is by dividing the maximum difference of criteria that included into discordance subsets with a maximum difference of the value of all the criteria. It is mathematically expressed as follows:

$$d_{kl} = \frac{\max\{|v_{kj} - v_{ij}|\}}{\max\{|v_{kj} - v_{ij}|\}}$$

Table 4.38 Matriks Discordances Calculate

Matriks Discordances				
	Alt 1	Alt 2	Alt 3	Alt 4
Alternative 1	0,00	1,00	1,00	1,00
Alternative 2	0,85	0	0,85	0,66
Alternative 3	1,00	1,00	0	1,00
Alternative 4	0,96	1,00	0,65	0

5. **Step 5: Determine Dominant Matriks Concordances and Discordances**

a. Calculating the dominant matrix concordance
   Matrix F as the dominant matrix concordance can be built with the help of threshold value, by comparing the value of each matrix element concordance with threshold value.

$$C_{kl} >= C$$

with a threshold value (c) are:

$$c = \frac{\sum_{k=1}^{m} \sum_{i=1}^{m} c_{kl}}{m\ (m-1\ )}$$

Threshold concordances = 72,88
so, the elements of the matrix F are determined as follow:

$$f_{kl} = \{\frac{1, if\ c_{kl} \geq c}{0, if\ c_{kl} < c}$$

Table 4.39 Matriks Concordances Threshold

Matriks Concordances				
	Alt 1	Alt 2	Alt 3	Alt 4
Alternative 1	0,00	0,00	1,00	0,00
Alternative 2	1,00	0,00	1,00	1,00
Alternative 3	1,00	0,00	0,00	0,00
Alternative 4	1,00	1,00	1,00	0,00

b. Calculating the dominant matrix concordance
   Matrix G as the dominant matrix can be built with the help of discordance threshold value:

$$d = \frac{\sum_{k=1}^{m}\sum_{l=1}^{m} d_{kl}}{m\,(m-1)}$$

Threshold discordances = 0,910
and elements of matrix G is determined as follows:

$$g_{kl} = \{\frac{1, if\ d_{kl} \geq c}{0, if\ d_{kl} < c}$$

Table 4.40 Matriks Discordances Threshold

Matriks Discordances				
	Alt 1	Alt 2	Alt 3	Alt 4
Alternative 1	0,00	1,00	1,00	1,00
Alternative 2	0,00	0,00	0,00	0,00
Alternative 3	1,00	1,00	0,00	1,00
Alternative 4	1,00	1,00	0,00	0,00

6. Step 6: Determine aggregate dominance matrix
   Matrix E Matrix E as the aggregate of dominant matrix is a matrix in which each element is the multiplication between matrix element F with the corresponding elements of matrix G, expressed as:

$$E_{kl} = f_{kl} \times g_{kl}$$

Table 4.41 Agregate Matriks Dominance

MATRIKS DOMINANCE				
	Alt 1	Alt 2	Alt 3	Alt 4
Alternative 1	0,00	0,00	1,00	0,00
Alternative 2	0,00	0,00	0,00	0,00
Alternative 3	1,00	0,00	0,00	0,00
Alternative 4	1,00	1,00	0,00	0,00

7. Step 7: Elimination less favorable alternative
   Matrix Matrix E gives the preferred order of each alternative if the alternative AK is a better alternative than Al. The line in matrix E which has the least number can be eliminated. Thus, the best alternative is the one that dominates the other alternatives. Based on Table 4.42, alternative 2 is less favourable

alternative and it should be eliminated, while alternative 4 has score 2.0 and alternative 1 and 3 has score 1.0. In ELECTRE implementation, the alternative selection is alternative 4 which has higher score than alternative 1 and 3. Alternative 4 is Submerged Combustion Vaporizer.

Table 4.42 Agregate Matriks Dominance

Alternatives	Value
Alternative 1	1,00
Alternative 2	0,00
Alternative 3	1,00
Alternative 4	2,00

4.3 Optimization SPB LNG and LNG Storage Tank

Conceptual design of mini LNG supply chain is to determine the components for distribution to power plants. In this research, the main components needed for optimization include the amount of self-propelled LNG barge, round trip, amount of LNG storage tank, and LNG Regasification Plant and Minium Total Cost of Investment.

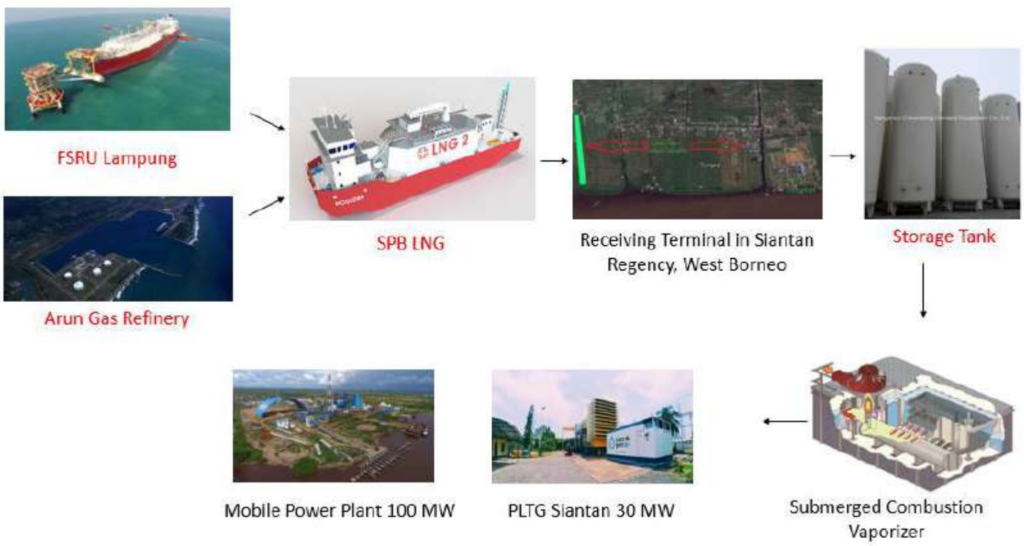


Figure 4.9 Mini LNG Supply Chain components

4.4.1 Optimization by Solver

Optimization is necessary to determine the minimum investment cost of mini LNG supply chain components to complete power plants demand. In this case the demand of power plants is 130 mw. The location of receiving terminal is in Siantan, West Borneo. Now we optimize the principal dimension of ship, amount of ship, ship route, the capacity of regasification, the capacity of LNG storage tank to optimize minimum cost investment. To optimize the mini LNG supply chain components, we can use 'solver' tool in Microsoft Excel. It has several tools for data analysis such as *scenario manager*, *what-if function, goal seek, tool pack analysis*, and *solver*. Solver is one of the Microsoft Excel tools which perform to solve simple problem to complex problem. Solver can calculate value needed to reach optimal result in a cell (range). Solver could solve problem which has several cell variable and solve the variable combination to minimize or maximize a value in a target cell.

Mathematics modeling in solver is a several comparison and non-comparison from one mathematic function. Mathematic function contains one or more variable decision and objective function to form the constrainst, where:

- *Decision variable* is a variable which represents the decision making.
- *Objective Function* is a criteria functions to reach the maximum or minimum value.
- *Constraint* is a condition to limit value from decision variable.
- *Decision variable value* which complete all constraints is feasible space. Meanwhile, decision variable which does not complete the decision value is infeasible space.
- *Objective Function* which is constrainted is an unbounded solution, and the two or more best objective function is called multiple optimal solution.
- Solver application will produce three report such as answer, sensitivity, and limit.

4.3.2 Data Identification

1. **Identification LNG Resorce**

   There are several LNG resources in Indonesia which have been used for domestics and exported to foreign countries until now, such as Arun Gas Refinery, FSRU Lampung which is received cargo from Tangguh, Badak Gas refinery, Natuna Gas Refinery, Donggi Sendoro LNG, and Tangguh LNG. West Borneo is located in coordinate 0.2788° S, 111.4753^0 E. The four nearest LNG resources are Natuna Gas Resource (429 nm), FSRU Lampung (480 nm), Bontang Gas Refinery (971 nm) Arun Gas Refinery (1073 nm). In this current condition, there is no LNG resource for domestic needs in Natuna Gas Refinery, because all cargo is exported to the foreign country. Same condition happens in Bontang LNG resource which has no resource for West Kalimantan because the cargo is allocated to Bali. Arun Gas refinery is also possible as a LNG resource for West Borneo to support Gas Power because there are about 0.6 MTPA with the price of LNG is approximately USD 6 per MMBTU but the distance is very far from West Borneo. Meanwhile FSRU lampung has the distance of 480 nautical miles from Mini LNG receiving terminal in West Borneo with 0.6 MTPA cargo available. For LNG resource, Arun Gas Refinery and FSRU Lampung are among the selection. Solver will determine which one has the most economical for LNG resource with investment period of 25 years.

Table 4.43 Identification LNG Resource

No	Route		Distances	Cargo	LNG Price
	LNG Resource	Receiving Terminal	nm	Availability	usd/mmbtu
1	Arun Gas Refinery	Siantan, West Borneo	840	0.6 MTPA	5
2	Bontang Gas Refinery	Siantan, West Borneo	973	0.6 MTPA	-
3	FSRU Lampung	Siantan, West Borneo	480	0.6 MTPA	7
4	Natuna Gas Refinery	Siantan, West Borneo	429	-	-

2. **Identification of LNG Carrier**

For LNG distribution from LNG resource to LNG Receiving Terminal, Self Propelled LNG Barge is used. Self Propelled Barge is good for sailing in shallow draft like in West Borneo. The depth Water in Siantan area is 5 meter maximum for ship sailing. Meanwhile Self-propelled LNG Barge data is designed for cargo capacity of 12000 m^3 with draft of 3.5 m. If Self Propelled LNG Barge is compared to Mini LNG carrier. The draft for cargo capacity of 7500 m^3 mini LNG carrier is 5.5 m. So, using Mini LNG carrier in West Borneo is not reliable.

Figure 4.10 Mini LNG Carrier Model Maximum Draft
(Wartsila, 2016)

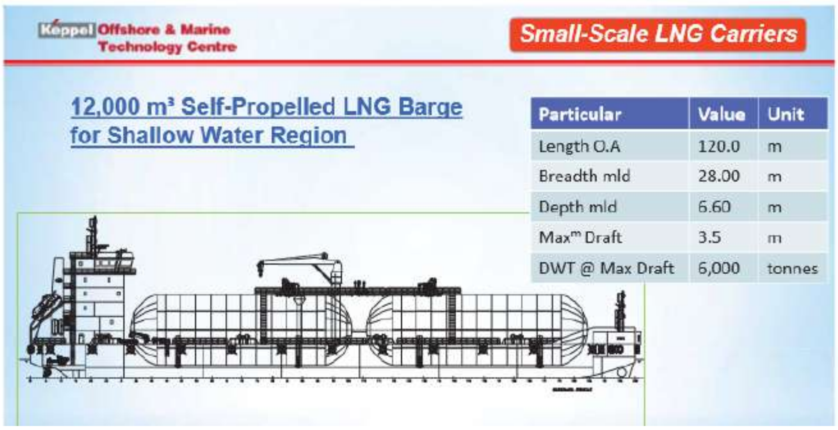


Figure 4.11 Self Propelled LNG Barge Maximum Draft
(Bashar, 2014)

Self-propelled LNG barge containment system is using Type C (Cylindrical) tank which is carried by ship barge. Type C tank has fixed capacity of 5000 m^3, 7500 m^3, 10000 m^3, and 12000 m^3. The data design from keppel (Table 4.42) for Self-Propelled LNG Barge has cargo pump capacity of 520 m^3/hour for 12000 m^3 SPB and the price is $60 million.

Table 4.44 Identification LNG Carrier Particular

No	SPB LNG Barge		Speed	Cargo Pump	Price
	Model	Cargo Capacity (m3)	(Knot)	(m3/hour)	USD
1	Keppel	12000	10	520	60.000.000
2	Own Design	10000	10	420	50.000.000
3	Keppel	7500	10	320	40.000.000

Self-Propelled LNG Barge fuel oil consumption (Table 4.43) for 12000 m^3 SPB LNG is 2800 Kw and main engine MDO consumption 4,46 ton/day. SPB LNG has 19 crews for ship operation.

Table 4.45 Identification of LNG carrier Fuel Oil Consumption

No	SPB LNG Barge		Main Engine	Main Engine	Ship
	Model	Main Engine Power (KW)	MDO (Ton/Day)	MFO (Ton/Day)	Crew
1	Keppel	2800	4,46	29,72	19
2	Own Design	2400	3,72	24,77	19
3	Keppel	1920	2,97	19,81	19

3. Identification of Receiving Terminal

After data analysis for location of receiving terminal, the result is in Siantan Regency (Onshore Facility). The technology of regasification unit is using Submerged Combustion Vaporizer (SCV). In reciving terminal there are two supplied power plants (PLTG MPP Jungkat 100 MW and PLTG Siantan 30 MW) by using one facility of LNG infrastructure.

Table 4.46 LNG Infrastructure in West Borneo

No	Power Plant		Power	Location	Regasification
	Name	Location	(MW)	Receiving Termial	Technology
1	PLTG MPP Jungkat	Siantan Regency	100	Siantan Regency (Onshore)	Submerged Combustion Vaporizer (SCV)
2	PLTG Siantan	Pontianak City	30		

Figure 4.12 Location of LNG Receiving Terminal in West Borneo

4. Identification of Regasification Plant

Regasification Plant chosen from multicriteria decision making is Submerged Combustion Vaporizer (SCV). LNG regasification or LNG Vaporizer purpose is to transfer heat from water bath to Liquefied natural gas (LNG). Then LNG become Natural gas which is required by power plants.

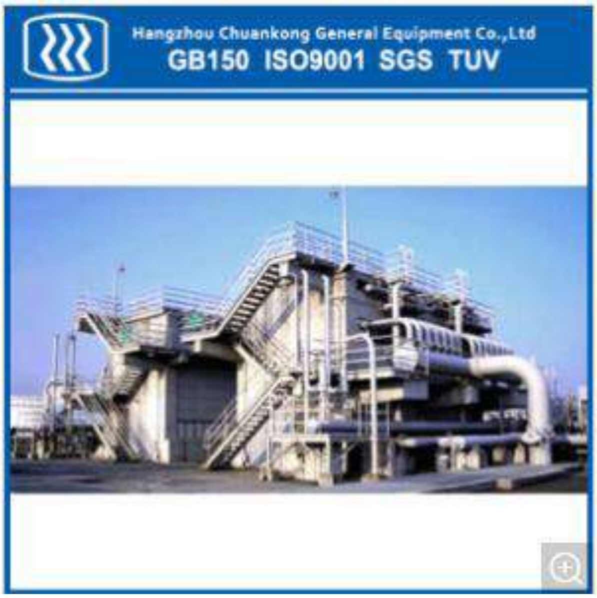


Figure 4.13 Hangzhou Submerged Combustion Vaporizer (Chuangkong, 2017)

Table 4.47 Identification of LNG carrier Fuel Oil Consumption (Chuangkong, 2017)

.

Model NO.:	SCV-30000
Purpose:	Viprozation Liquid
Noise Level:	Low
Condition:	New
Capacity:	30 - 180t/H
Type:	Scv
Seawater Flowrate: ~	6550m3/H
Trademark:	Hang Tong
Usage:	LNG
Application Fields:	Chemical
Machine Size:	Medium - Large
Certification:	ISO, GB, ASME
LNG Side Operation Pressure:	8.88MPa
LNG Side Design Pressure:	13.9MPa
Load Adjustment Range:	10~110%
Specification:	QQ-180T

5. Identification Storage Tank

LNG storage tank is cryogenic tank. It can keep LNG temperature in -161 degree celcius. Storage Tank Volume depends on LNG carrier Capacity. If LNG carrier capacity is 7500 m^3, then the storage tank must be equal or more than 7500 m^3. The storage tank volume is varied. The capacity is from 50 m^3–50000 m^3. Storage tank amount and volume can be optimize to get the most economical investment in mini LNG infrastucture. Tank model capacity below (Figure 4.11) is from 150 m^3, 200 m^3, and 300 m^3.

Figure 4.14 Hangzhou LNG Storage Tank
(Chuangkong, 2017)

Table 4.48 LNG Storage Tank 300 m3 Project Guide
(Chuangkong, 2017)

Model NO.	ZCF-300/22
Customized	Customized
Tank Marerial	Metal Tank
Storage Objects	Liquid, Gas
Trademark	Hang Tong
Origin	China
Condition	New
Certification	ISO9001, SGS, GB, ASME
Type	Low Temperature Storage & Transportation Equipment
Color	White
Specification	300m3
Price	USS 200000
Weight	173000 kg
Size	4236 mm x 32360 mm

Table 4.49 LNG Storge Tank 200 m3 Project Guide
(Chuangkong, 2017)

Model NO.	ZCF-200000/8
Customized	Customized
Tank Marerial	Metal Tank
Storage Objects	Liquid, Gas
Trademark	Hang Tong
Origin	China
Condition	New
Certification	ISO9001, SGS, GB, ASME
Type	Low Temperature Storage & Transportation Equipment
Color	White
Specification	200m3
Price	USS 150000
Weight	89070 kg
Size	3824mm x 29000 mm

Table 4.50 LNG Storage tank 150 m3 Project Guide
(Chuangkong, 2017)

Model NO.	ZCF-150000/6
Customized	Customized
Tank Marerial	Metal Tank
Storage Objects	Liquid, Gas
Trademark	Hang Tong
Origin	China
Condition	New
Certification	ISO9001, SGS, GB, ASME
Type	Low Temperature Storage & Transportation Equipment
Color	White
Specification	150m3
Price	USS 100000
Weight	60060 kg
Size	3732mm x 21115 mm

4.3.3 Mathematics Model

Mathematic model is used to give symbol to the notes. It can create the formula to calculate the conceptual design data. Table 4.64 shows the mathematic model.

Table 4.51 Mathematics model symbols

Symbol		Notes
INVijk	=	Ship Investment Cost
Deff	=	Ship operation time in a year (couting in days)
Sij	=	Distance from i to power plant j
Vk	=	Ship Velocity when carrying cargo
CSijk	=	cargo ship capacitywhich is carried from i to j
Lk	=	Time for unloading and loading kapal
DWk	=	DWT of Ship
RTDijk	=	Ship round trip in days from i to j
RTYijk	=	Ship round trip in years from i to j
Vijk	=	Ship voyage trip to complete demand of power plant
DMj	=	Power Plant Demand j
Ssj	=	Safety Stock in Power Plant
Pport	=	Port Charge
NMFO	=	MFO Consumption
NHFO	=	HFO Consumption
PMFO	=	Price of MFO
PHFO	=	Price of HFO
Mk	=	Maximum capacity of Ship cargo

4.3.4 Mathematics Model in Optimization Voyage

a. Round Trip

Round Trip is the time needed by a ship to complete one trip from i to j until the ship comes back to i. In this conceptual design. The voyage trip of SPB LNG is planned from FSRU Lampung or Arun Gas Refinery to Receiving Terminal in Siantan to supply two power plants (PLTG MPP Jungkat and PLTG Siantan). If it is created in mathematics model, the model will be

$$\text{RTD}ijk = seatimeijk + port\ timeijk$$

Seatime is the time needed for a ship to sail the distance *Sij* by velocity *Vk*. The mathematic model will be:

$$Seatime\ ijk = \frac{s_{ij}}{i_{jk}}$$

Port time is the time needed for a ship to unload all LNG in ship cargo in receiving terminal. The influencing aspects of port time is the capacity of storage tank of Ship of CSijk and unloading time of Lk. The mathematic model of Port time will be:

$$\text{Port time ijk} = 2 \times \frac{CSi_{jk}}{lk}$$

b. Bunkering Cost

Fuel oil concumption on main engine is Heavy Fuel Oil (HFO) and Medium Diesel Oil (MDO). Consumption of oil fuel depends on specific oil fuel consumption of main engine. It must be known that SFOC of main engine in catalogue is to calculate the total consumption of oil fuel. On this catalogue of main engine, consumption of oil fuel is determined by ton/day. Mathematic model of bunkering cost is:

Price for HFO*ijk* = N*HFOijk* * RTY*ijk* * P*HFO*
Price for MDO*ijk* = N*MDOijk* * RTY*ijk* * P*MDO*

Bunkering cost is total oil fuel consumption for ship in one round trip per year. Source from PT. Pertamina, Price of MFO (PHFO) is Rp. 6350/Liter and Price of MDO (PMDO) is Rp. 8810/liter.

c. Freight Cost

Total freight cost **=** (Investment on Ship) + (2*Port Charge) + Bunker Consumption Cost + Crew cost + Insurance cost

a. Investment cost on ship = DWT of Ship *Cost of Steel Weight (US$/Ton)
   Investment cost per year =DWk*INSijk

b. Port Charge = 2*Port cost ij *Chargo Ship capacityijk *Voyageijk
   Pport = 2*(Pport* CSijk*Vijk)

c. Bunker consumption cost = Bunkering Cost for Sea Time + Port Time
   Bunkering Cost for Sea Time = bunker consumption * Round trip per year * bunker cost

   Bunkering cost for port Time = 20% Bukering Cost of sea time
   - RTD*ijk = seatimeijk + port timeijk + Slack time*
   - *Bunkering* HFO*ijk* = N*HFOijk**RTY*ijk** P*HFO*
   - *Bunkering MDOijk* =N*MDOijk**RTY*ijk**P*MDO*

d. *Insurance Cost = Cargo ship capacityijk*Ins. Costij* RTYijk*
Insurance cost= CS*ijk**P*insij**RTY*ijk*

4.3.5 Optimization Model in FSRU Lampung

The Trace of Objective function is created thus the total of investment cost can be calculated. Data Input of optimization such as, cost of SPB building, cost of bunkering, cost of crew, cost of port charge and etc., as shown in table below.

a. Self Propelled LNG Barge 7500 m3

Self-propelled LNG barge project guide is from keppel offshore technology. The specification of SPB LNG barge is particularly shown in table 4.52.

Table 4.52 SPB LNG Barge 7500 particulars model
(Bashar, 2014)

SPB LNG 7500 m3			
No	Data		Unit
1	LOA	82,8	m
2	B	25	m
3	H	7	m
4	T	4	m
5	Cargo Capacity	3750	Ton
6	Cargo Capacity	7500	m3
7	Speed	10	knot
8	Cargo Pump Capacity	625	m3/hours
9	Main Engine	1920	Kw
10	MFO Consumption	19,81	ton/day
11	MDO Consumption	2,97	ton/day
12	Number of Ship Crew	19	Person
13	Operational Ship	360	Days

1. Round Trip
   Round Trip Duration = Sea Time + Port Time + Slack Time

   Sea Time = 2* Distance to Receiving Terminal/Ship Speed
   = 2* Sij/Vk
   = 2* (480/10)
   = 96 Hours
   Port Time = 2 * Cargo capacity/Cargo pump Velocity

= 2* (Mijk/Qk)
= 2* (7500/625)
= 24 Hours

Slack Time = Assume 2 days
= 48 Hours

Round Trip Duration = Sea Time + Port Time + Slack Time
= 96 + 24 + 48
= 168 Hours

2. Ship Operational Days
   Ship operational days = 360 Days
   = 360 * 24 hours
   = 8640 Hours

3. Maximum Total Round Trip per year
   Total Round Trip = LNG Demand / Cargo Capacity
   = 362000/7500
   = 49,7 trip/year

4. Ship Cost
   Self Propelled LNG Barge cost is $40.000.000
5. Insurance Cost
   Premi Cost = 3.84 USD/ton
   Insurance Cost = cargo ship capacity *premi *round trip/year
   Insurance Cost = 3750 ton * 3.84 USD/ton * voyage
   = 705600 USD

6. Port Charge Cost
   Port cost = 4.24 USD/ton
   Port charge cost = cargo capacity * port cost * round trip/year
   Port charge cost = 3750 * 4.24 * 49
   = 1558200 USD

7. Bunkering Cost
   MDO Cost = 662 USD/ton
   MFO Cost = 519 USD/ton

Consumption MDO at sea time = MDO consumption *Sea time *Total round trip * price of MDO
= 19.81 ton/day * 4 days *49 trip * 662 USD/ton
= 1.594.879 USD/year

Consumption MDO at port time = Days in Port Time * Consumption of MDO * 20%
= 19.268 USD/year

Consumption MFO at sea time = HDO consumption *Sea time *Total round trip * price of HFO
= 2.97 ton/day * 4 days * 49 trip * 519 USD/ton
= 170.302 USD/year

Consumption MFO at port time = Days in Port Time * Consumption of MFO * 20%
= 100757 USD/year

Bunkering Cost = total consumption MDO + MFO
= 3015082 USD + 321963 USD
= 1785361 USD/year

8. Jetty Contruction Cost
   Cost for jetty construction is US$1.890.000.
9. LNG Storage Tank Cost
   LNG storge tank cost is calculated to get the minimum investment. By using solver calculation, the most minimum invetsment to complete 7500 m^3 of LNG storage tank is 25 tanks with the capacity of 300 m^3. The investment cost is US$ 5.089.718.

Table 4.53 SPB LNG Barge 7500 particulars model

Input		Tank 1	Tank 2	Tank 3
	Capacity (m3)	300	200	150
	Tank cost (USD)	200000	140000	100000
	Land Demand (m2)	17,943696	14,622976	13,927824
	Land Cost/m2	200		
Constraint	Constraint			
	LHS	Symbol		RHS
	7500	>=		7500
Output	Total Tank	25	0	0
Objective Function	Total Investment	USD 5.089.718		

b. Self Propelled LNG Barge 10000 m3

Self-propelled LNG barge project guide is made by keppel offshore technology. The specification of SPB LNG barge is particularly shown in Table 4.55.

Table 4.54 SPB LNG Barge 10000 m3 particulars model (Bashar, 2014)

No	Data		Unit
1	LOA	103	m
2	B	26	m
3	H	8,1	m
4	T	5,4	m
5	Cargo Capacity	5000	Ton
6	Cargo Capacity	10000	m3
7	Speed	10	knot
8	Cargo Pump	840	m3/hour
9	Main Engine	2400	Kw
10	MFO Consumption	24,77	ton/day
11	MDO Consumption	3,72	ton/day
12	Number of Ship Crew	19	Person
13	Operational Ship	360	Days

1. Round Trip

   Round Trip Duration = Sea Time + Port Time + Slack Time

Sea Time = 2 * Distance to Receiving Terminal/Ship Speed
= 2* Sij/Vk
= 2* (480/10)
= 96 Hours

Port Time = 2 * Cargo capacity/Cargo pump Velocity
= 2* (Mijk/Qk)
= 2* (10000/840)
= 24 Hours

Slack Time = Assume 2 days
= 48 Hours

Round Trip Duration = Sea Time + Port Time + Slack Time
= 96 + 24 + 48
= 168 Hours

2. Ship Operational Days
   Ship operational days = 360 Days
   = 360 * 24 hours
   = 8640 Hours

3. Maximum Total Round Trip per year
   Total Round Trip = LNG Demand/ Ship Cargo Capacity
   = 362000 / 10000
   = 36,2 trip/year

4. Ship Cost
   Self Propelled LNG Barge 10000 m3 cost is $50.000.000
5. Insurance Cost
   Premi Cost = 3.84 USD/ton
   Insurance Cost = Cargo Ship Capacity*Premi*Round Trip/year
   Insurance Cost = 5000 ton * 3.84 USD/ton * 36,2 trip per year
   = 695040 USD

6. Port Charge Cost
   Port Cost = 4.24 USD/ton
   Port Charge Cost = Cargo Capacity * Port Cost * round trip/year

Port Charge Cost = 5000 * 4.24 * 36,2
= 1534880 USD

7. Bunkering Cost
   MDO Cost = 662 USD/ton
   MFO Cost = 519 USD/ton
   Consumption MDO at sea time = MDO consumption *Sea time *Total round trip * price of MDO
   = 24.77 ton/day * 4 days *36 trips * 662 USD/ton
   = 356.590 USD/year

   Consumption MDO at port time = Days in Port Time * Consumption of MDO * 20%
   = 17.731 USD/year
   Consumption MFO at sea time = HDO consumption *Sea time *Total round trip * price of HFO

   = 2.97 ton/day * 4 days * 49 trip * 519 USD/ton
   = 1861495 USD/year
   Consumption MFO at port time = Days in Port Time * Consumption of MFO * 20%
   = 92560 USD/year

   Bunkering Cost = total consumption MDO + MFO
   = 3015082 USD + 321963 USD
   = 1785361 USD/year

8. Jetty Contruction Cost
   Jetty Constructioncost for ship 10000 m3 is US$2.310.000.

9. LNG Storage Tank Cost
   LNG storge tank cost is also calculated by using solver to get minimum investment. By using solver calculation the most minimum invetsment to complete 10000 m^3 LNG storage tank is 34 tanks with the capacity of 300 m^3. The investment cost needed is US$ 6.922.017.

Table 4.55 SPB LNG Barge 10000 m3 particulars model

Input		Tank 1	Tank 2	Tank 3
	Capacity (m3)	300	200	150
	Tank cost (USD)	200000	140000	100000
	Land Demand (m2)	17,943696	14,622976	13,927824
	Land Cost/m2	200		
Constraint	Constraint			
	LHS	Symbol		RHS
	10200	>=		10000
Output	Total Tank	34	0	0
Objective Function	Total Investment	USD 6.922.017		

c. Self Propelled LNG Barge 12000 m3

Self-propelled LNG barge project guide is from keppel offshore technology. The specification of SPB LNG barge is particularly shown in Table 4.69 below.

Table 4.56 SPB LNG Barge 12000 m3 particulars model
(Bashar, 2014)

SPB LNG 12000 m3			
No	Data		Unit
1	LOA	120	m
2	B	28	m
3	H	6,6	m
4	T	3,5	m
5	Cargo Capacity	6000	Ton
6	Cargo Capacity	12000	m3
7	Speed	10	knot
8	Cargo Pump	1040	m3/hour
9	Main Engine	2800	Kw
10	MFO Consumption	29,77	ton/day
11	MDO Consumption	4,46	ton/day
12	Number of Ship Crew	19	Person
13	Operational Ship	360	Days

1. Round Trip
   Round Trip Duration = Sea Time + Port Time + Slack Time

   Sea Time = 2 *Distance to Receiving Terminal/Ship Speed
   = 2* Sij/Vk
   = 2* (480/10)
   = 96 Hours
   Port Time = 2 * Cargo capacity/Cargo pump Velocity
   = 2* (Mijk/Qk)
   = 2* (12000/1040)
   = 24 Hours

   Slack time = Assume 2 days
   = 48 Hours

   Round trip duration = Sea Time + Port Time + Slack Time
   = 96 + 24 + 48
   = 168 Hours

2. Ship Operational Days
   Ship operational days = 360 Days
   = 360 * 24 hours
   = 8640 Hours
3. Maximum Total Round Trip per year
   Total round trip = LNG demand/ cargo capacity
   = 362000/ 12000
   = 31 trip/year

4. Ship Cost
   Self Propelled LNG Barge12000 m3 cost is US$60.000.000

5. Insurance Cost
   Premi Cost = 3.84 USD/ton
   Insurance Cost = Cargo Ship Capacity *premi *Round Trip/year
   Insurance Cost = 6000 ton * 3.84 USD/ton * 31 trip per year
   = 690040 USD

6. Port Charge Cost
   Port Cost = 4.24 USD/ton

Port Charge Cost = cargo capacity *port cost *round trip/year
Port Charge Cost = 6000 * 4.24 * 31
= 1.534.880 USD

7. Bunkering Cost
   MDO Cost = 662 USD/ton
   MFO Cost = 519 USD/ton

   Consumption MDO at sea time = MDO consumption *Sea time *Total round trip * price of MDO
   = 19.81 ton/day * 4 days *49 trip * 662 USD/ton
   = 356.270 USD/year

   Consumption MDO at port time = Days in Port Time * Consumption of MDO * 20%
   = 18.305 USD/year

   Consumption MFO at sea time = HDO consumption *Sea time *Total round trip * price of HFO
   = 2.97 ton/day * 4 days * 49 trip * 519 USD/ton
   = 1.864.376 USD/year

   Consumption MFO at port time = Days in Port Time * Consumption of MFO * 20%
   = 95.739 USD/year

   Bunkering Cost = total consumption MDO + HFO
   = 3015082 USD + 321963 USD
   = 2.334.746 USD/year

8. Jetty Construction Cost
   Jetty construction cost is US$ 2.310.000.

9. LNG Storage Tank Cost
   LNG storge tank cost is also calculated by using solver to get minimum investment. By using solver calculation, the most minimum investment to complete 12000 m3 LNG storage tank is using 40 tanks with the capacity of 300 m3. The investment cost needed is US$8.143.550.

Table 4.57 LNG Storage Tank for 12000 m3 optimization

Input		Tank 1	Tank 2	Tank 3
	Capacity (m3)	300	200	150
	Tank cost (USD)	200000	140000	100000
	Land Demand (m2)	17,943696	14,622976	13,927824
	Land Cost/m2	200		
Constraint	Constraint			
	LHS	Symbol		RHS
	12000	>=		12000
Output	Total Tank	40	0	0
Objective Function	Total Investment	USD 8.143.550		

4.3.5.1 Optimization Voyage Trip

a. Input

This table shows input for all calculation of voyage optimization.

Table 4.58 LNG Storage Tank for 12000 m3 optimization

	7500 m3	10000 m3	12000 m3
Total Investment Cost	$50.885.101	$62.995.553	$74.617.724
Cargo Capacity (m3)	7500	10000	12000
Hours per trip (hours)	168	168	168
Demand LNG (m3)	362000		
Operational/year (hours)	8640		

b. Constraint

Constraint is a limitation of value to optimize the maximum or minimum output. Constraint which is applied in this conceptual design is:

- Cargo capacity carried must be ≥ Demand of Power plant. In this case, the cargo capacity carried must be ≥ 362000 m^3/year.
- Total of round trip must be ≤ total of ship operational time.
- Ship operational time must be ≤ than availability of ship operational. In this case is 360 days per year or 8640 hours/year.

- Amound of Ship must be = 1, so only one ship will be choosen for this round trip. Round trip must be integer
- Amound of ship must be = 1 and binary

c. Output and Objective Function

The most minimum investment of conceptual design is using 1 LNG barge capacity 7500 m3 with 49 round trip per year. The total cost of LNG barge cost, Insurance Cost, Port Charge cost, Bunkering Cost, Jetty Construction Cost, and LNG Storage tank cost is US$50.885.101,50. (see table 4.60)

Table 4.59 FSRU Lampung Optimization Result

Input	Investment Cost	$51.604.535,59	$63.668.297,04	$75.294.666,30
	Cargo Capacity	7500 m3	10000 m3	12000 m3
	Hours per trip	168	168	168
	Demand	362000		
	Operational hours/year	8640		
Constraint			Inequality	
	Demand	367500	>=	362000
		0	>=	0
		0	>=	0
	Operational Hours	8232	<=	8640
		0	<=	0
		0	<=	0
	Ship amound	1	=	1
Output	Amound of Ship	1	0	0
	Total Round Trip	49	0	0
Objective function	Investment Cost	**$51.604.535,59**		

4.3.6 Optimization Model in Arun Gas Refinery

The Trace of Objective function is created to calculate the total investment cost. Data Input of optimization such as, cost of SPB building, cost of bunkering, cost of crew, cost of port charge and etc as shown in table below.

a. Self Propelled LNG Barge 7500 m3

By using the same formula as optimization in Arun, the result's shown below.

Table 4.60 LNG Storage Tank for 7500 m3 optimization

No	Parameter	Calculation	Unit
1	Round trip	49	Trip/year
2	Operational Days	8640	Hours/year
3	Ship Building Cost	40.000.000	Usd/unit
4	Insurance Cost	695.040	Usd/unit
5	Port Charge Cost	1.534.880	Usd/year
6	Total Bunkering Cost	4.258.070	Usd/year
7	Jetty Construction	1890.000	Usd/Unit
8	LNG Storage Tank Cost	5.000.000	Usd/ total unit

b. Self Propelled LNG Barge 10000 m3

By using the same formula as optimization in Arun, the result's shown below.

Table 4.61 LNG Storage Tank for 10000 m3 optimization

No	Parameter	Calculation	Unit
1	Round trip	36	Trip/year
2	Operational Days	8640	Hours/year
3	Ship Building Cost	50.000.000	Usd/unit
4	Insurance Cost	695.040	Usd/unit
5	Port Charge Cost	1.534.880	Usd/year
6	Total Bunkering Cost	3.991.941	Usd/year
7	Jetty Construction	2310.000	Usd/Unit
8	LNG Storage Tank Cost	6.800.000	Usd/ total unit

c. Self Propelled LNG Barge 12000 m3

By using the same formula as optimization in Arun, the result's shown below.

Table 4.62 LNG Storage Tank for 12000 m3 optimization

No	Parameter	Calculation	Unit
1	Round trip	31	Trip/year
2	Operational Days	8640	Hours/year
3	Ship Building Cost	60.000.000	Usd/unit
4	Insurance Cost	695.040	Usd/unit
5	Port Charge Cost	1.534.880	Usd/year
6	Total Bunkering Cost	4.000.231	Usd/year
7	Jetty Construction	2.730.000	Usd/Unit
8	LNG Storage Tank Cost	8.000.000	Usd/ total unit

From those tables all parameter to optimize self-propelled LNG barge has different in bunkering cost. While others parameter looks almost similar.

4.3.6.1 Optimization Voyage Trip

This table shows input for all calculation of voyage optimization.

a. Input

This table shows input for all calculation of voyage optimization.

Table 4.63 Input for Optimization Voyage Trip

Total Investment Cost	\$53.377.977	\$65.331.861	\$76.960.151
Cargo Capacity (m3)	7500	10000	12000
Hours per trip (hours)	240	240	240
Demand LNG (m3)	362000		
Operational/yer (hrs)	8640		

b. Constraint

Constraint is a limitation of value to optimize the maximum or minimum output. Constraints applied in this conceptual design are:

- Cargo capacity carried must be ≥ Demand of Power plant. In this case, the cargo capacity carried must be ≥ 362000 m^3/year.
- Total of round trip must be ≤ total of ship operational time.
- Ship operational time must be ≤ than availability of ship operational. In this case is 360 days per year or 8640 hours/year.
- Amound of Ship must be = 1, so only one ship will be choosen for this round trip. Round Trip must be integer
- Amound of ship must be = 1
- Amound of ship must be binary

c. Output and Objective Function

The most minimum investment of conceptual design is 1 LNG barge with capacity of 12000 m3 with 31 round trip per year. The total cost of LNG barge cost, Insurance Cost, Port Charge cost, Bunkering Cost, Jetty Construction Cost, and LNG Storage tank cost is US\$75.861.077,60. (see table 4.65)

Table 4.64 Output and Objective Function

Input	Investment Cost	$53.377.977,93	$65.331.861,16	$76.960.151,37
	Cargo Capacity	7500	10000	12000
	Hours per trip	240	240	240
	Demand	362000		
	Operational hours/year	8640		
Constraint		LHS	Inequality	RHS
	Demand	0	>=	0
		0	>=	0
		372000	>=	362000
	Operational Hours	0	<=	0
		0	<=	0
		7440	<=	8640
	Ship amound	1	=	1
Output	Amound of Ship	0	0	1
	Total Round Trip	0	0	31
Objective Function	Investment Cost	**$76.960.151,37**		

4.3 Economic Feasibility Study (Source in FSRU Lampung)

4.4.1 Capital Expenditure

Capital Expenditure is the fixed cost necessary to build the infrastructure. Capital cost is spent in the first year of investment. In the table below, there are several capital cost necessary for building mini LNG infrastructure.

Table 4.65 LNG Storage Tank for 12000 m3 optimization

No	Investment	Specs	Cost	Unit	Total	Total Cost
1	SPB LNG	7500 m3	$40.000.000	usd	1 Unit	$40.000.000
2	Jetty		$1.890.000	usd	1 Unit	$1.890.000
3	Supporting Building		$450.349	usd	1 Unit	$450.349
4	Office Inventory		$100.000	usd	1 Unit	$100.000
5	Control Room		$450.349	usd	1 Unit	$450.349
6	Land Investment + Dredging		$100	usd/m2	15000 m2	$1.500.000
7	Marine Loading arm		$750.526	usd/unit	1 Unit	$750.536
8	Tie Fender	Type v 250 h L 3000	$44.432	usd/unit	3 Unit	$44.432
9	Electric Power Generator		$375,00	usd/kw	500 kw	$187.500
10	Generator Set	350 KVA	$54.054	usd/set	1 unit	$54.054
		250 KVA	$52.548	usd/set	0 unit	
		150 KVA	$50.296	usd/set	0 unit	
11	LNG Storage Tank	300 m3	$200.000	usd/unit	25 unit	$5.000.000
		200 m3	$150.000	usd/unit	0 unit	$-
		150 m3	$100.000	usd/unit	0 unit	$-
12	LNG pump		$250.000	usd/unit	2 unit	$500.000
13	BOG Compressor		$250.000	usd/unit	2 unit	$500.000
14	LNG Vaporizer (SCV)		$450.000	usd/unit	2 unit	$900.000
15	Cryogenic Pipe		$1.300	usd/m/inch	500 unit	$650.000
16	Gas Send out (Onshore)		$68,00	usd/m/inch	16000 m*2,5 inch	$2.720.000
17	Valve Equipment		$1.000.000	usd/total plant	1 Unit	$1.000.000

Table 4.65 LNG Storage Tank for 12000 m3 optimization (continued)

18	Flow Meter		$150.000	usd/package	30 Unit	$4.500.000
19	Pressure transmitter		$1.000.000	usd/total	1 Unit	$1.000.000
20	Fire Fighting Equipment		$750.000	usd/package	2 Unit	$1.000.000
21	Nitrogen System		$300.000,00	usd/package	1 Unit	$300.000
22	Safety Equipment		$750.000,00	usd/package	2 unit	$1.500.000
23	Mooring Equipment		$1.126.000,00	usd/Total Equipment	1 Unit	$1.126.000
24	Equipment Installation Cost		$213.954,00	usd/Total Installation	1 Unit	$213.954
Total Capital Expenditure						$66.839.174

4.4.2 Operational Expenditure

Operational expenditure is necessary cost to operate infrastructure. Mini LNG infrastructure operational costs such as receiving terminal cost, ship-to-ship operational cost and ship operational cost are shown in table below.

1. **Receiving Terminal Operational Cost**

a. **Port Charge**

Port charge is a cost for ship berthing in receiving terminal. If the ship is berthing in Indonesia terminal such as West Borneo, then shipowner needs to pay the cost according to the round trip and cargo capacity. Port charge for SPB LNG Barge 7500 m^3 is shown in Table 4.79 below.

Table 4.66 Port charge calculation per year

Port charge	$4,24	usd/ton
Round Trip	49	trip/year
Cargo Capacity	3750	Ton LNG
Port Charge	**$779.100,00**	**usd/year**

b. **Regasification Cost**

Regasification technology is used for building mini LNG infrastructure in West Borneo is Submerged Combustion Vaporizer (SCV). This technology utilizes marine diesel oil to heat water bath. Water bath is used to transfer heat to

LNG. Therefore, cost is needed to use marine diesel oil. The calculation of regasification cost is shown in the Table below.

Table 4.67 Regasification cost calculation

Price of MDO =	$417,00	usd/ton
Regasification comsumption =	0,09	ton/day
MDO consumption per day =	$37,53	usd/day
Regasification cost per year =	$13.698,45	usd/year

c. Maintenance Cost

Receiving terminal sets of many important equipment and supportig equipment such as LNG pump, BOG compressor, LNG vaporizer, LNG strage tank ad etc. They will produce cost to maintain to keep the asset is up in performance. Maintenance cost for alla sset in receiving terminal is US$100.000/total asset/year.

d. Employee Salary Cost

Operating mini LNG infrastructure needs human resource and organization. In this case, it is planned to recruit 25 employees in which each of them needs payment. The detail is shown in table below.

Table 4.68 Human resources plan and salary

Office Salary				
Position	total	Salary/Position	Salary/Month	Salary/Year
CEO	1	$2.800,00	$2.800,00	$33.600,00
General Manager	1	$2.500,00	$2.500,00	$30.000,00
Head of Superintendent	1	$2.500,00	$2.500,00	$30.000,00
Head of Engineer	1	$2.500,00	$2.500,00	$30.000,00
Head of Port Safety Agency	1	$2.500,00	$2.500,00	$30.000,00
Head of Finance	1	$2.500,00	$2.500,00	$30.000,00
Head of HRD	1	$2.000,00	$2.000,00	$24.000,00
Junior Superintendent	2	$900,00	$1.800,00	$21.600,00
Staff of Engineer	4	$800,00	$3.200,00	$38.400,00
Staff of Port Safety Agency	2	$800,00	$1.600,00	$19.200,00
Staff of HRD	2	$600,00	$1.200,00	$14.400,00
Staff of Finance	2	$600,00	$1.200,00	$14.400,00

Table 4.68 Human Resources Plan and Salary (continued)

Receptionist	2	\$300,00	\$600,00	\$7.200,00
Security	2	\$350,00	\$700,00	\$8.400,00
Office Boy	2	\$250,00	\$500,00	\$6.000,00
Total	**25**	**Total Salary/year**		**\$337.200,00**

e. Employee Insurance Cost

Employee insurance cost is needed because human resources is working on high-risk area. The following table presents the data of employee insurance cost for each position.

Table 4.69 Employee Insurance

Employee Insurance		
Position	Quantity	Insurance per year
CEO	1	\$1.500,00
General Manager	1	\$1.000,00
Head of Superintendent	1	\$1.000,00
Head of Engineer	1	\$1.000,00
Head of Port Safety Agency	1	\$1.000,00
Head of Finance	1	\$1.000,00
Head of HRD	1	\$1.000,00
Junior Superintendent	2	\$500,00
Staff of Engineer	4	\$500,00
Staff of Port Safety Agency	2	\$500,00
Staff of HRD	2	\$500,00
Staff of Finance	2	\$500,00
Receptionist	2	\$300,00
Security	2	\$300,00
Office Boy	2	\$300,00
Total	**25**	**\$10.900,00**

f. Employee Accomodation Cost

Accomodation for crew is necessary to support their work. The detail calculation is shown in table below.

Table 4.70 Employee Accomodation Cost

Employee Accomodation		
Position	Quantity	Accomodation per year
CEO	1	$1.800,00
General Manager	1	$1.800,00
Head of Superintendent	1	$1.800,00
Head of Engineer	1	$1.800,00
Head of Port Safety Agency	1	$1.800,00
Head of Finance	1	$1.800,00
Head of HRD	1	$1.800,00
Junior Superintendent	2	$1.000,00
Staff of Engineer	4	$1.000,00
Staff of Port Safety Agency	2	$1.000,00
Staff of HRD	2	$1.000,00
Staff of Finance	2	$1.000,00
Receptionist	2	$1.000,00
Security	2	$1.000,00
Office Boy	2	$1.000,00
Total	**25**	**$20.600,00**

g. Office Building Inventory Cost

Office building in receiving terminal is necessary for document and human resource as the working area. The inventory cost is spent every five year according to table below.

Table 4.71 Office Building Inventory

Asset	Unit	Cost per Unit	Total Cost
Computer	20	$700,00	$14.000,00
Printer	4	$800,00	$3.200,00
Central Air Conditioner	4	$1.000,00	$4.000,00
Office Table	20	$300,00	$6.000,00
Office Chair	30	$100,00	$3.000,00
Telephone + Fax	2	$300,00	$600,00
Office Tools	10	$500,00	$5.000,00
Office Car	2	$20.000,00	$40.000,00
Total			**$75.800,00**

h. Cost of Energy

Cost of energy in this case is electricity, telephone, Wi-Fi connectivity, and fresh water. The cost of energy is shown in table below.

Table 4.72 Cost of Energy

Power	Month	Cost per Month	Total Cost per year
Cost of Electricity	12	$10.000,00	$120.000,00
Cost of Telephone	12	$800,00	$9.600,00
Cost of Wifi	12	$250,00	$3.000,00
Cost of Fresh Water	12	$100,00	$1.200,00
Total Cost			$133.800,00

2. Ship to Ship Cargo Transfer Operational Cost

a. STS Port Charge

When ship is loading cargo in FSRU Lampung, the ship has to conduct ship-to-ship cargo transfer which requires port charge cost. The cost is shown in table below.

Table 4.73 Ship to Ship port charge

Port charge	$4,24	usd/ton
Round Trip	49	trip/year
Cargo Capacity	3750	Ton LNG
Port Charge cost	$779.100,00	usd/year

3. LNG Barge Operational Cost

a. Bunkering Cost

Bunkering cost is oil fuel consumption necessary for main engine to sail around the round trip. SPB LNg barge is using two different kinds of oil fuel. The calculation is shown in table below.

Table 4.74 Bunkering cost

Price of MFO	$519,00	usd/ton
MFO Consumption per day	19,81	ton/day
MFO Consumption per year	3882,76	ton/year
Cost for MFO Consumption	$2.015.152,44	usd/year
MFO Consumption per day =	2,97	ton/day
MFO Consumption per year =	582,12	ton/year

Cost for MFO Consumption =	$385.363,44	usd/year
Total Consumption Bunkering	$2.400.515,88	usd/year

b. Ship Maintenance Cost

SPB LNG also need to maintain the main equiment and supporting equipment such as diesel generator, main engine, pump and etc. Maintenance cost for all asset in receiving terminal is US$100.000/total asset/year.

c. Ship Insurance Cost

SPB LNG premi for this case is US$3,84 per ton. The total cost per year for ship insurance cost is shown in table below.

Table 4.75 Ship Insurance Cost

Premi =	$3,84	usd/ton
Voyage =	49	Trip/year
Cargo Capacity =	3750	Ton LNG
Ship Insurance cost =	$705.600,00	usd/year

d. Crew Salary Cost

The insurance cost is needed because human resource is working on high-risk area. The following table explains the insurance cost for each crew position.

Table 4.76 Crew Salary Cost

Office Salary				
Position	Quantity	Salary/Position	Salary/Month	Salary/Year
Captain	1	$2.500	$2.500	$30.000,00
Chief Engineer	1	$2.200	$2.200	$26.400,00
Chief Officer	1	$2.200	$2.200	$26.400,00
Second Engineer	1	$1.700	$1.700	$20.400,00
Second Officer	1	$1.700	$1.700	$20.400,00
Third Engineer	1	$1.400	$1.400	$16.800,00
Third Officer	1	$1.400	$1.400	$16.800,00
Quarter Master	3	$900	$2.700	$32.400,00
Foreman	1	$800	$800	$9.600,00
Oiler	3	$800	$2.400	$28.800,00
Chef	2	$600	$1.200	$14.400,00

Mess Boy	2	$400	$800	$9.600,00
Cadet	1	$150,00	$150,00	$1.800,00
Total	**19**	**Total Salary/year**		**$253.800,00**

e. Crew Insurance Cost

Crew insurance cost is needed because Human resources is working on high risk area. In each insurance cost has its cost which is shown in table below.

Table 4.77 Crew Insurance Cost

Insurance per year		
Position	Quantity	Insurance per year
Captain	1	$2.000,00
Chief Engineer	1	$1.500,00
Chief Officer	1	$1.500,00
Second Engineer	1	$1.500,00
Second Officer	1	$1.000,00
Third Engineer	1	$1.000,00
Third Officer	1	$1.000,00
Quarter Master	3	$500,00
Foreman	1	$500,00
Oiler	3	$500,00
Chef	2	$500,00
Mess Boy	2	$500,00
Cadet	1	$300,00
Total	**19**	**$12.300,00**

f. Crew Accomodation Cost

Accomodation for crew is necessary to support their work. The detail calculation is shown in table below.

Table 4.78 Crew Accomodation Cost

Crew Accomodation		
Position	Quantity	Accomodation per year
Captain	1	$2.000,00
Chief Engineer	1	$2.000,00
Chief Officer	1	$2.000,00
Second Engineer	1	$2.000,00
Second Officer	1	$2.000,00
Third Engineer	1	$2.000,00
Third Officer	1	$2.000,00
Quarter Master	3	$1.000,00
Foreman	1	$1.000,00
Oiler	3	$1.000,00
Chef	2	$1.000,00
Mess Boy	2	$1.000,00
Cadet	1	$1.000,00
Total	**19**	**$20.000,00**

g. Ship Classification Cost

Every ship needs to be classified and requires cost for process. The cost for classification is US$100.000 per year.

h. Document & Administration Cost

Ship needs to be commisioned to have a valid certificate. Ship must be seaworthiness. It needs cost to test the ship and get the document. The total cost per year or ship document is US$100.000 per year. Operational cost total in first year of investment is $5.383.899.

4.4.3 Investment cost for 25 years

Acoording to Bank Indonesia, if investor would like to loan finance to invest for building infrastructure, they have to pay the tax for 15% and interest for 12% per year. The loan finance must be paid in 10 years. Investment will begin in 2020 because it needs a lot of time to build the SPB LNG. It also takes time to order main and supporting equipment to build mini LNG Infrastructure. First investment is assumed to use 50% of loan finance and 50% of own finance. The table below shows the investment cost necessary which experience 8% inflation per year according to the capital expediture and operational expenditure.

Table 4.79 Investment cost in 2020 – 2024

Cost	Year				
	2020	2021	2022	2023	2024
Capital Expenditure	$68.816.840				
Bunkering	$2.400.515	$2.400.515	$2.400.515	$2.400.515	$2.400.515
Port Charge	$779.100	$779.100	$779.100	$779.100	$779.100
Regasification	$13.698	$13.698	$13.698	$13.698	$13.698
Office Inventory	$75.800	-	-	-	-
Power	$133.800	133.800	133.800	133.800	133.800
Employee	$337.200	$337.200	$337.200	$337.200	$337.200
Employee Insurance	$10.900	$10.900	$10.900	$10.900	$10.900
Accomodation	$20.600	$20.600	$20.600	$20.600	$20.600
Maintenance	$100.000	$100.000	$100.000	$100.000	$100.000
Port Charge in STS	$779.100	$779.100	$779.100	$779.100	$779.100
Ship Insurance	$705.600	$705.600	$705.600	$705.600	$705.600
Crew Salary	$253.800	$253.800	$253.800	$253.800	$253.800
Crew Insurance	$12.300	$12.300	$12.300	$12.300	$12.300
Crew Accomodation	$20.000	$20.000	$20.000	$20.000	$20.000
Ship Maintenance	$200.000	$200.000	$200.000	$200.000	$200.000
Classification	$100.000	-	-	-	-
Document	$50.000	-	-	-	-
TOTAL	$74.809.254	$5.766.614	$5.766.614	$5.766.614	$5.766.614
Own Finance					
Percentage	50%				
Absolute	37.404.627,17				
Total of Own Finance	37.404.627,17				
Loan Finance					
Percentage	50%				
Absolute	37.404.627,17				
Total of Loan Finance	37.404.627,17				

Capital expenditure is spent in the first year of investment to build mini LNG infrastructure. Classification and document cost is spent every five years according to the ship renewal class. The calculation of investment cost in 2025 to 2029 is shown in table below.

Table 4.80 Investment cost in 2025 – 2029

Cost	Year				
	2025	2026	2027	2028	2029
Capital Expenditure	$-	$-	$-	$-	$-
Bunkering	$2.592.557	$2.592.557	$2.592.557	$2.592.557	$2.592.557
Port Charge	$841.428	$841.428	$841.428	$841.428	$841.428
Regasification	$14.794	$14.794	$14.794	$14.794	$14.794
Office Inventory	$81.864	$-	$-	$-	$-
Power	$144.504	$144.504	$144.504	$144.504	$144.504
Employee	$364.176	$364.176	$364.176	$364.176	$364.176
Employee Insurance	$11.772	$11.772	$11.772	$11.772	$11.772
Accomodation	$22.248	$22.248	$22.248	$22.248	$22.248
Maintenance	$108.000	$108.000	$108.000	$108.000	$108.000
Port Charge in STS	$841.428	$841.428	$841.428	$841.428	$841.428
Ship Insurance	$762.048	$762.048	$762.048	$762.048	$762.048
Crew Salary	$274.104	$274.104	$274.104	$274.104	$274.104
Crew Insurance	$13.284	$13.284	$13.284	$13.284	$13.284
Crew Accomodation	$21.600	$21.600	$21.600	$21.600	$21.600
Ship Maintenance	$216.000	$216.000	$216.000	$216.000	$216.000
Classification	$108.000	$-	$-	$-	$-
Document	$54.000	$-	$-	$-	$-
TOTAL	$6.471.807	$6.227.943	$6.227.943	$6.227.943	$6.227.943

For other costs, it is assumed to be increased for 8% per five year according to the Indonesian's track record of inflation. Investment for 2030 to 2034 is shown in table below.

Table 4.81 Investment cost in 2030 – 2034

Cost	Year				
	2030	2031	2032	2033	2034
Capital Expenditure	$-	$-	$-	$-	$-
Bunkering	$2.799.961	$2.799.961	$2.799.961	$2.799.961	$2.799.961
Port Charge	$908.742	$908.742	$908.742	$908.742	$908.742
Regasification	$15.977	$15.977	$15.977	$15.977	$15.977
Office Inventory	$88.413	$-	$-	$-	$-
Power	$156.064	$156.064	$156.064	$156.064	$156.064
Employee	$393.310	$393.310	$393.310	$393.310	$393.310
Employee Insurance	$12.713	$12.713	$12.713	$12.713	$12.713
Accomodation	$24.027	$24.027	$24.027	$24.027	$24.027

Table 4.92 Investment cost in 2030 – 2034 (continued)

Maintenance	$116.640	$116.640	$116.640	$116.640	$116.640
Port Charge in STS	$908.742	$908.742	$908.742	$908.742	$908.742
Ship Insurance	$823.011	$823.011	$823.011	$823.011	$823.011
Crew Salary	$296.032	$296.032	$296.032	$296.032	$296.032
Crew Insurance	$14.346	$14.346	$14.346	$14.346	$14.346
Crew Accomodation	$23.328	$23.328	$23.328	$23.328	$23.328
Ship Maintenance	$233.280	$233.280	$233.280	$233.280	$233.280
Classification	$116.640	$-	$-	$-	$-
Document	$58.320	$-	$-	$-	$-
TOTAL	$6.989.552	$6.726.178	$6.726.178	$6.726.178	$6.726.178

Investment cost in 2035 to 2040 is shown in table below.

Table 4.82 Investment cost in 2035 – 2039

Cost	Year				
	2035	2036	2037	2038	2039
Capital Expenditure	$-				
Bunkering	$3.023.958	$3.023.958	$3.023.958	$3.023.958	$3.023.958
Port Charge	$981.441	$981.441	$981.441	$981.441	$981.441
Regasification	$17.256	$17.256	$17.256	$17.256	$17.256
Office Inventory	$95.486	$-	$-	$-	$-
Power	$168.549	$168.549	$168.549	$168.549	$168.549
Employee	$424.774	$424.774	$424.774	$424.774	$424.774
Employee Insurance	$13.730	$13.730	$13.730	$13.730	$13.730
Accomodation	$25.950	$25.950	$25.950	$25.950	$25.950
Maintenance	$125.971	$125.971	$125.971	$125.971	$125.971
Port Charge in STS	$981.441	$981.441	$981.441	$981.441	$981.441
Ship Insurance	$888.852	$888.852	$888.852	$888.852	$888.852
Crew Salary	$319.714	$319.714	$319.714	$319.714	$319.714
Crew Insurance	$15.494	$15.494	$15.494	$15.494	$15.494
Crew Accomodation	$25.194	$25.194	$25.194	$25.194	$25.194
Ship Maintenance	$251.942	$251.942	$251.942	$251.942	$251.942
Classification	$125.971	$-	$-	$-	$-
Document	$62.985	$-	$-	$-	$-
TOTAL	$7.548.716	$7.264.273	$7.264.273	$7.264.273	$7.264.273

Investment cost in 2035 to 2040 is shown in table below.

Table 4.83 Investment cost in 2040 - 2044

Cost	Year				
	2040	2041	2042	2043	2044
Capital Expenditure	$-	$-	$-	$-	$-
Bunkering	$3.265.875	$3.265.875	$3.265.875	$3.265.875	$3.265.875
Port Charge	$1.059.956	$1.059.956	$1.059.956	$1.059.956	$1.059.956
Regasification	$18.636	$18.636	$18.636	$18.636	$18.636
Office Inventory	$103.125	$-	$-	$-	$-
Power	$182.033	$182.033	$182.033	$182.033	$182.033
Employee	$458.756	$458.756	$458.756	$458.756	$458.756
Employee Insurance	$14.829	$14.829	$14.829	$14.829	$14.829
Accomodation	$28.026	$28.026	$28.026	$28.026	$28.026
Maintenance	$136.048	$136.048	$136.048	$136.048	$136.048
Port Charge in STS	$1.059.956	$1.059.956	$1.059.956	$1.059.956	$1.059.956
Ship Insurance	$959.961	$959.961	$959.961	$959.961	$959.961
Crew Salary	$345.292	$345.292,	$345.292,	$345.292,	$345.292,
Crew Insurance	$16.734	$16.734	$16.734	$16.734	$16.734
Crew Accomodation	$27.209	$27.209	$27.209	$27.209	$27.209
Ship Maintenance	$272.097	$272.097	$272.097	$272.097	$272.097
Classification	$136.048	$-	$-	$-	$-
Document	$68.024	$-	$-	$-	$-
TOTAL	$8.152.613	$7.845.415	$7.845.415	$7.845.415	$7.845.415

After all calculation of investment from 2020 – 2045 the total of mini LNG infrastructure investment is $ 199.759.30,00.

4.4.4 LNG Cost in FSRU Lampung

LNG demand in West Borneo is 36200 m3 LNG/year. LNG cost in FSRU Lampung according to PGN data is very fluctuative in the range of US$5.5–6.5 per mmbtu. In this case, it is assumed that per mmbtu will cost US$7 for giving space to the fluctuative price. So the cost for 1 m3 cargo LNG is 21,2 mmbtu x US$ 7/mmbtu then the result is US$148,40/m3. The calculation for LNG cost in 25 years is shown in table below.

Table 4.84 LNG cost in FSRU Lampung

Product	Cargo Price per m3	Years				
		2020	2021	2022	2023	2024
LNG	$148,40	$148,40	$148,40	$148,40	$148,40	$148,40
LNG Cost		$53.720.800	$53.720.800	$53.720.800	$53.720.800	$53.720.800
Product	Cargo Price per m3	Years				
		2025	2026	2027	2028	2029
LNG	$148,40	$148,40	$148,40	$148,40	$148,40	$148,40
LNG Cost		$53.720.800	$53.720.800	$53.720.800	$53.720.800	$53.720.800
Product	Cargo Price per m3	Years				
		2030	2031	2032	2033	2034
LNG	$148,40	$148,40	$148,40	$148,40	$148,40	$148,40
LNG Cost		$53.720.800	$53.720.800	$53.720.800	$53.720.800	$53.720.800
Product	Cargo Price per m3	Years				
		2035	2036	2037	2038	2039
LNG	$148,40	$148,40	$148,40	$148,40	$148,40	$148,40
LNG Cost		$53.720.800	$53.720.800	$53.720.800	$53.720.800	$53.720.800
Product	Cargo Price per m3	Years				
		2040	2041	2042	2043	2044
LNG	$148,40	$148,40	$148,40	$148,40	$148,40	$148,40
LNG Cost		$53.720.800	$53.720.800	$53.720.800	$53.720.800	$53.720.800
Total			$1.343.020.000,00			

4.4.5 Depresiation Asset

Mini LNG infrastructure has several asset that is used for operational. The asset reliability will go down and may impact the asset value. Mini LNG infrastructure has classified into 2 types of asset: mini LNG receiving terminal and SPB LNG Barge 7500 m^3. Value of asset is assumed to experience depresiation in number of 2% linierly. Total asset value is US$68.816.840 and will be depresiated for 25 years with the number of asset value US$34.408.420 as shown in table below.

Table 4.85 Depresiation Asset

Asset	age asset (year)	Value asset	% Depresiation
SPB LNG 7500 m3	25	$40.000.000	2
Mini LNG Receiving Terminal	25	$28.816.840	2
Total		$68.816.840	

Year				
2020	2021	2022	2023	2024
$800.000	$800.000	$800.000	$800.000	$800.000
$576.336	$576.336	$576.336	$576.336	$576.336
$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336
Year				
2020	2021	2022	2023	2024
$800.000	$800.000	$800.000	$800.000	$800.000
$576.336	$576.336	$576.336	$576.336	$576.336
$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336
Year				
2020	2021	2022	2023	2024
$800.000	$800.000	$800.000	$800.000	$800.000
$576.336	$576.336	$576.336	$576.336	$576.336
$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336
Year				

Table 4.85 Depresiation Asset (continued)

2020	2021	2022	2023	2024
$800.000	$800.000	$800.000	$800.000	$800.000
$576.336	$576.336	$576.336	$576.336	$576.336
$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336
Year				
2020	2021	2022	2023	2024
$800.000	$800.000	$800.000	$800.000	$800.000
$576.336	$576.336	$576.336	$576.336	$576.336
$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336	$-1.376.336
Value of Asset after 25 year				
FIRST VALUE		$68.816.840,00		
DECREASE		$-34.408.420,00		
ASSET AFTER 25 YEARS		$34.408.420,00		

4.4.6 Revenue

Revenue is cash back of investment by selling product to the consuments which is not included tax. Product of LNG will be sold to the consuments in West Borneo in amount of 362.000 m3/year. Revenue must be higher than the investment cost to get a higher profit. Revenue will be variated according to NPV, IRR, and payback period value. Revenue will be variated in margin range US$2 - US$3 per mmbtu. The table below shows the revenue with margin US$2.5/mmbtu.

Table 4.86 Revenue of Operation

Product	Cargo Price per m3	Years				
		2020	2021	2022	2023	2024
LNG	$222,60	$222,60	$222,60	$222,60	$222,60	$201,40
LNG Cost		$80.581.200	$80.581.200	$80.581.200	$80.581.200	$80.581.200

Product	Cargo Price per m3	Years				
		2025	2026	2027	2028	2029
LNG	$222,60	$222,60	$222,60	$222,60	$222,60	$201,40
LNG Cost		$80.581.200	$80.581.200	$80.581.200	$80.581.200	$80.581.200
Product	Cargo Price per m3	Years				
		2030	2031	2032	2033	2034
LNG	$222,60	$222,60	$222,60	$222,60	$222,60	$222,60
LNG Cost		$80.581.200	$80.581.200	$80.581.200	$80.581.200	$80.581.200
Product	Cargo Price per m3	Years				
		2035	2036	2037	2038	2039
LNG	$201,40	$222,60	$222,60	$222,60	$222,60	$222,60
LNG Cost		$53.720.800	$80.581.200	$80.581.200	$80.581.200	$80.581.200
Product	Cargo Price per m3	Years				
		2040	2041	2042	2043	2044
LNG	$201,40	$222,60	$222,60	$222,60	$222,60	$222,60
LNG Cost		$53.720.800	$80.581.200	$80.581.200	$80.581.200	$80.581.200
Total		$1.822.670.000,00				

4.4.7 Cash Flow

Cash flow is report of all transaction (cash outflow) and all total revenue (cash inflow) of an operation in one period. Cash flow in mini LNG plant operation is the total of all capital expenditure, operational expenditure, tax and interest of loan finance. Table below shows cash inflow and cash outflow of mini LNG plant operation in 2020–2025.

Table 4.87 Cash Flow in 2020 to 2024

Notes	2020	2021	2022	2023	2024
Total Revenue	$80.581.200	$80.581.200	$80.581.200	$80.581.200	$80.581.200
Total Cost	$59.713.214	$59.487.414	$59.487.414	$59.487.414	$59.487.414
Cash Flow Operation	$20.867.986	$21.093.786	$21.093.786	$21.093.786	$21.093.786
Cash Flow Include Tax	$15.650.989	$15.820.339	$15.820.339	$15.820.339	$15.820.339
Investment:					
Ship Building	$40.000.000				
Receiving Terminal	$28.816.840				
PMT	$6.620.026	$6.620.026	$6.620.026	$6.620.026	$6.620.026
Depresiation :	$1.376.337	$1.376.337	$1.376.337	$1.376.337	$1.376.337
Total	$76.813.203	$7.996.363	$7.996.363	$7.996.363	$7.996.363
Surplus/Deficit	$-61.162.214	$7.823.976	$7.823.976	$7.823.976	$7.823.976
Balance in Period	$-	$-61.162.214	$-53.338.238	$-45.514.263	$-37.690.287
Balance in Period	$-61.162.214	$-53.338.238	$-45.514.263	$-37.690.287	$-29.866.311

Table below shows the cash inflow and cash outflow of mini LNG plant operation in 2025–2029.

Table 4.88 Cash Flow in 2025 to 2029

Notes	2025	2026	2027	2028	2029
Total Revenue	$80.581.200	$80.581.200	$80.581.200	$80.581.200	$80.581.200
Total Cost	$60.192.607	$59.948.743	$59.948.743	$59.948.743	$59.948.743
Cash Flow Operation	$20.388.593	$20.632.457	$20.632.457	$20.632.457	$20.632.457
Cash Flow Include Tax	$15.291.444	$15.474.342	$15.474.342	$15.474.342	$15.474.342
Investment:					
Ship Building					
Receiving Terminal					
PMT	$6.620.026	$6.620.026	$6.620.026	$6.620.026	$6.620.026

Table 4.89 Cash Flow in 2025 to 2029 (continued)

Depresiation :	$1.376.337	$1.376.337	$1.376.337	$1.376.337	$1.376.337
Total	$1.376.337	$1.376.337	$1.376.337	$1.376.337	$1.376.337
Surplus/Deficit	$7.295.081	$7.477.979	$7.477.979	$7.477.979	$7.477.979
Balance in Period	$-29.866.311	$-22.571.230	$-15.093.251	$-7.615.272	$-137.293
Balance in Period	$-22.571.230	$-15.093.251	$-7.615.272	$-137.293	$7.340.686

Table below shows the cash inflow and cash outflow of mini LNG plant operation in 2030–2034.

Table 4.89 Cash Flow in 2030 to 2034

Notes	2030	2031	2032	2033	2034
Total Revenue	$80.581.200	$80.581.200	$80.581.200	$80.581.200	$80.581.200
Total Cost	$60.710.352	$60.446.979	$60.446.979	$60.446.979	$60.446.979
Cash Flow Operation	$19.870.848	$20.134.221	$20.134.221	$20.134.221	$20.134.221
Cash Flow Include Tax	$14.903.136	$17.114.088	$17.114.088	$17.114.088	$17.114.088
Investment:					
Ship Building	$-				
Receiving Terminal	$-				
Depresiation:					
Depresiation :	$1.376.337	$1.376.337	$1.376.337	$1.376.337	$1.376.337
Total	$1.376.337	$1.376.337	$1.376.337	$1.376.337	$1.376.337
Surplus/Deficit	$13.526.799	$15.737.751	$15.737.751	$15.737.751	$15.737.751
Balance in Period	$7.340.686	$20.867.485	$36.605.236	$52.342.987	$68.080.738
Balance in Period	$20.867.485	$36.605.236	$52.342.987	$68.080.738	$83.818.489

Table below shows cash inflow and cash outflow of mini LNG plant operation in 2035–2039.

Table 4.90 Cash Flow in 2035 to 2039

Notes	2035	2036	2037	2038	2039
Total Revenue	$80.581.200	$80.581.200	$80.581.200	$80.581.200	$80.581.200
Total Cost	$61.269.516	$60.985.073	$60.985.073	$60.985.073	$60.985.073
Cash Flow Operation	$19.311.684	$19.596.127	$19.596.127	$19.596.127	$19.596.127
Cash Flow Include Tax	$14.483.763	$14.697.095	$14.697.095	$14.697.095	$14.697.095
Investment:					
Ship Building					
Receiving Terminal					
Depresiation:					
Depresiation :	$1.376.337	$1.376.337	$1.376.337	$1.376.337	$1.376.337
Total	$1.376.337	$1.376.337	$1.376.337	$1.376.337	$1.376.337
Surplus/Deficit	$13.107.426	$13.320.758	$13.320.758	$13.320.758	$13.320.758
Balance in Period	$83.818.489	$96.925.915	$110.246.674	$123.567.432	$136.888.190
Balance in Period	$96.925.915	$110.246.674	$123.567.432	$136.888.190	$150.208.948

Table below shows cash inflow and cash outflow of mini LNG plant operation in 2040–2044.

Table 4.91 Cash Flow in 2040 to 2044

Notes	2040	2041	2042	2043	2044
Total Revenue	$80.581.200	$80.581.200	$80.581.200	$80.581.200	$80.581.200
Total Cost	$61.873.414	$61.566.215	$61.566.215	$61.566.215	$61.566.215
Cash Flow Operation	$18.707.786	$19.014.985	$19.014.985	$19.014.985	$19.014.985
Cash Flow Include Tax	$14.030.840	$14.261.239	$14.261.239	$14.261.239	$14.261.239
Investment:					
Ship Building	$-				
Receiving Terminal	$-				
Depresiation:					

Table 4.91 Cash Flow in 2040 to 2044 (continued)

Depresiation :	$1.376.337	$1.376.337	$1.376.337	$1.376.337	$1.376.337
Total	$1.376.337	$1.376.337	$1.376.337	$1.376.337	$1.376.337
Surplus/Deficit	$12.654.503	$12.884.902	$12.884.902	$12.884.902	$12.884.902
Balance in Period	$150.208.948	$162.863.451	$175.748.353	$188.633.255	$201.518.157
Balance in Period	$162.863.451	$175.748.353	$188.633.255	$201.518.157	$214.403.059

4.4.8 PMT (Payment)

PMT, one of the financial functions, calculates the payment for a loan based on constant payments and constant interest rate. In this investment, loan must be done in 10 years of operation. PMT formula in microsoft excel is PMT (rate,nper,pv).

Notes

- Rate : Interest (percent)
- Nper : time for loan (year).
- PV : Total Loan

In this case, the loan for investment is US$37.404.627,17. So the PMT in Microsoft Excel will be PMT(12%,10, 37.404.627,17) and the PMT for one year is US$6.620.026,65 (constant in 10 year).

4.4.9 Economic Feasibility Study if LNG in FSRU Lampung is \$7 per mmbtu

a. **Net Present Value (NPV)** approach gives the project contribution toward the total value of a firm which means positive contribution from a project will directly add value to the firm or vice versa. It is calculated using this formula:

$$\text{NPV} = \sum_{t=0}^{n} \frac{bt-ct}{(1+i)^2}$$

Net Present Value of this project is \$1.520.574.

b. **Internal rate return (IRR)** criterion is an evaluation approach very similar to NPV method. It also discounts the cash inflows and cash outflows of the project. It is calculated using this formula:

$$\text{IRR} = i_1 + \frac{npv_1}{npv_1 - npv_2}(i_1 - i_2)$$

Internal Rate Return is 12,33%

c. **Payback Period (PP)** is an evaluation approach to compare the initial cash outlay with the subsequent annual cash inflows of the project in order to determine the number of years needed to recover the initial investment. The table below shows total net cash flow and the value of payback period of this investment. Payback period is 9,70 year operation.

Table 4.92 Payback Period and Present Value

Year to	Year	Total Net Cash Flow	PP	Present value
1	2.020	\$-62.601.164,19	\$-62.601.164,19	\$-50.080.931,35
2	2.021	\$6.385.025,81	\$-56.216.138,39	\$4.086.416,52
3	2.022	\$6.385.025,81	\$-49.831.112,58	\$3.269.133,21
4	2.023	\$6.385.025,81	\$-43.446.086,77	\$2.615.306,57
5	2.024	\$6.385.025,81	\$-37.589.955,82	\$2.092.245,26
6	2.025	\$5.856.130,95	\$-31.550.926,88	\$1.535.149,59
7	2.026	\$6.039.028,95	\$-25.511.897,93	\$1.266.476,16
8	2.027	\$6.039.028,95	\$-19.472.868,98	\$1.013.180,93
9	2.028	\$6.039.028,95	\$-13.433.840,03	\$810.544,74
10	2.029	\$6.039.028,95	\$-7.394.811,09	\$648.435,80
11	2.030	\$12.087.849,14	\$4.693.038,06	\$1.038.338,34
12	2.031	\$14.106.941,09	\$18.799.979,15	\$969.421,61

Table 4.92 Payback Period and Present Value (continued)

13	2.032	$14.106.941,09	$32.906.920,23	$775.537,29
14	2.033	$14.106.941,09	$47.013.861,32	$620.429,83
15	2.034	$14.106.941,09	$61.120.802,41	$496.343,86
16	2.035	$11.668.476,02	$72.789.278,43	$328.438,40
17	2.036	$11.881.808,25	$84.671.086,68	$267.554,54
18	2.037	$11.881.808,25	$96.552.894,93	$214.043,63
19	2.038	$11.881.808,25	$108.434.703,17	$171.234,90
20	2.039	$11.881.808,25	$120.316.511,42	$136.987,92
21	2.040	$11.215.553,05	$131.532.064,46	$103.445,22
22	2.041	$11.445.951,85	$142.978.016,31	$84.456,22
23	2.042	$11.445.951,85	$154.423.968,17	$67.564,97
24	2.043	$11.445.951,85	$165.869.920,02	$54.051,98
25	2.044	$11.445.951,85	$177.315.871,87	$43.241,58

a. LNG selling US$9.75 (Margin US$2.75)

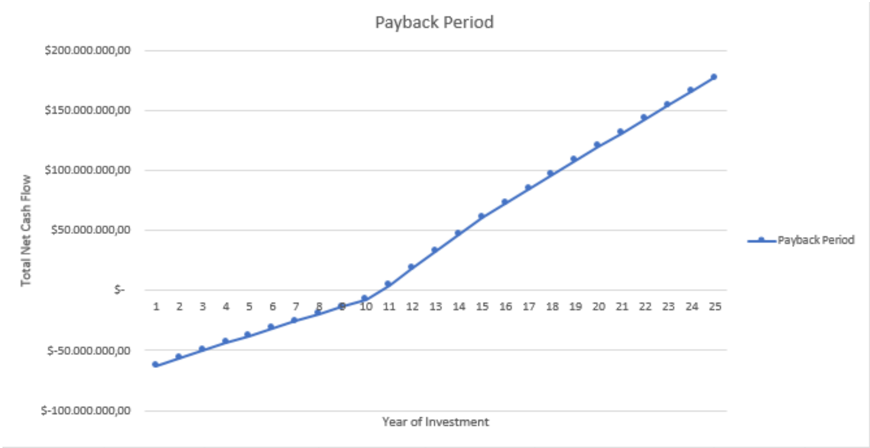
If the LNG is sold to the consuments in margin US$2.75 per mmbtu, the Investment is not feasible.

b. LNG selling US$10.00 (Margin US$3.00)

If the LNG is sold to the consuments in margin US$3.00 per mmbtu, the Investment is not feasible.

c. LNG Selling US$10.25 (Margin US$3.25)

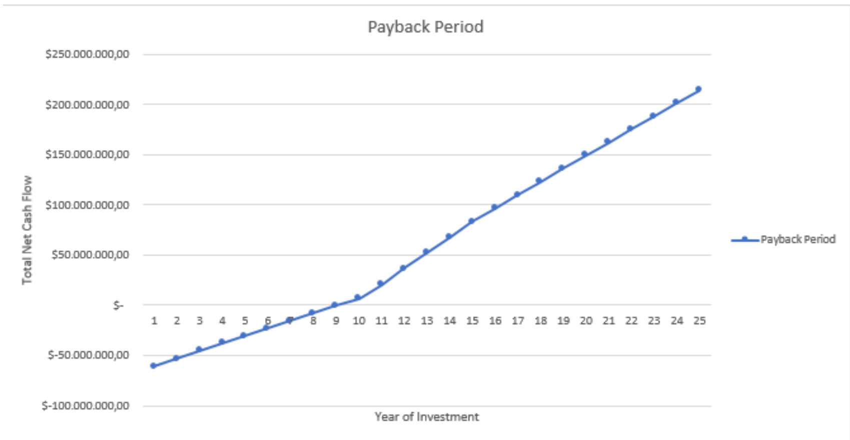
Graphic below shows the total net cash flow and year of investment if the LNG is sold $10.25 (margin $3.25 per mmbtu). It is shown that the payback period is about 10,50 year operation.



Graphic 4.1 Payback Period if LNG selling $10.25 per mmbtu

d. LNG Selling $ 10.50 (Margin $ 3.50)

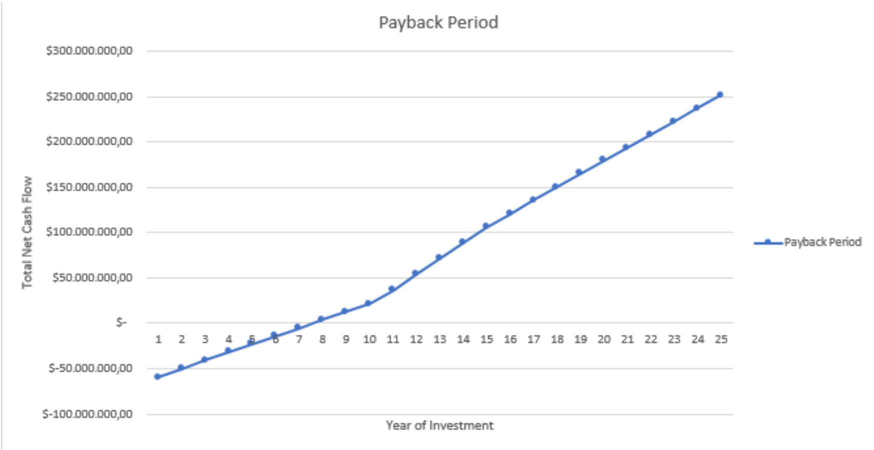
Graphic below shown the total net cash flow and year of investment if the LNG is sold $10.50 (margin $3.50 per mmbtu), the graphic shown the payback period will become about 8,90 year operation.



Graphic 4. 2 Payback Period if LNG selling $10.50 per mmbtu

e. LNG Selling $ 10.75 (Margin $ 3.75)

Graphic below shows the total net cash flow and year of investment if the LNG is sold for US$10.50 (margin US$3.50 per mmbtu). It is shown that the payback period is about 8,90 year operation.



Graphic 4.3 Payback Period if LNG selling $10.75 per mmbtu

d. Data Recapitulation

Margin variation functions to give the value of NPV, IRR, and payback period in variation of margin (profit). The conclusion is this investment is feasible if the minimum margin is US$2.75 - US$3.75 per mmbtu with positive NPV and IRR value. While if the margin is US$2.5 per mmbtu, the NPV value is negative which means the investment is not feasible. Detail value is shown in table below.

Table 4.93 Data Recapitulation in FSRU Lampung if LNG is $7 per mmbtu

FSRU LAMPUNG				Interest	12%
				LNG Cost per mmbtu	$7,00
LNG Selling per mmbtu	$9,75	$10,00	$10,25	$10,50	$10,75
Margin	$2,75	$3,00	$3,25	$3,50	$3,75
NPV	$- 21.386.246,85	$- 9.932.836,32	$1.520.574,21	$12.973.984,74	$24.427.395,27
IRR	7,46%	9,89%	12,33%	14,81%	17,37%
Payback Period	-	-	10,50 year	8,90 year	7,80 year
Investment	Not Feasible	Not Feasible	Feasible	Feasible	Feasible

4.4.10 Economic Feasibility Study if LNG cost $ 6 per mmbtu

LNG price in Indonesia is very fluctuative, the price now depends on the President's decision. There is a plan that President will confirm the LNG price in Indonesia to be $6 per mmbtu. So, the economic feasibility will be calculated with LNG price in FSRU Lampung US$6 per mmbtu. The result of calculation below (Table 4.109) shows that is LNG selling is US$10.25 per mmbtu, then the value of NPV will be US$35.612.795, The Value of IRR will be 19.62% and Payback period is 5.10 year of operation.

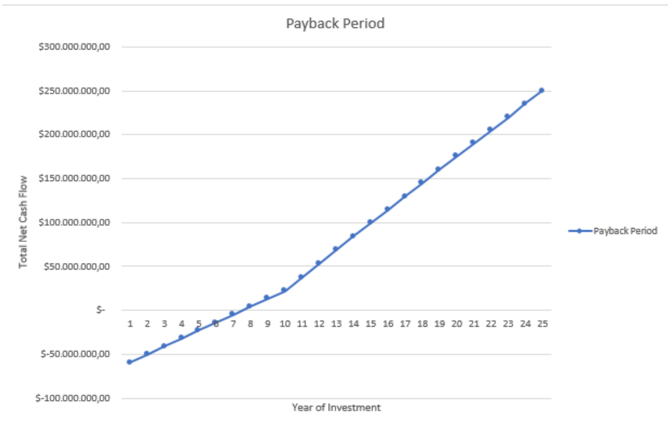
Table 4.94 Economic Feasibility Study if LNG cost is $ 6 per mmbtu

No	Variable	Value
1	LNG Cost	$ 6 per mmbtu
2	LNG Selling	$ 10.25 per mmbtu
3	Margin	$4,25
4	Net Present Value (NPV)	$46.266.382,60
5	Internal Rate Return (IRR)	23,78%

Payback Period of LNG selling will be shown in graphic below.

a. LNG selling $ 9.75 (Margin $ 3.75)

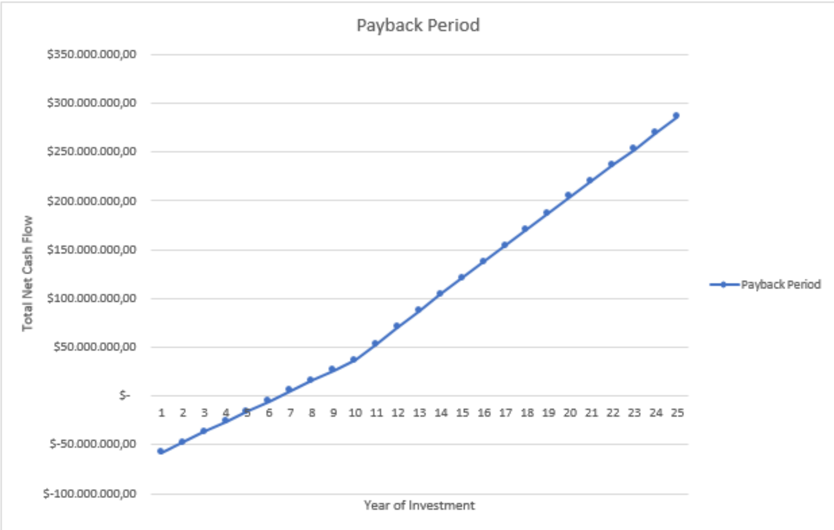
If the LNG is sold for US$9.75 (margin US$3.75 per mmbtu), the graphic shows that the payback period is about 7,80 year operation.



Graphic 4.4 Payback Period if LNG selling $9.75 per mmbtu

b. LNG selling $ 10.00 (Margin $ 4.00)

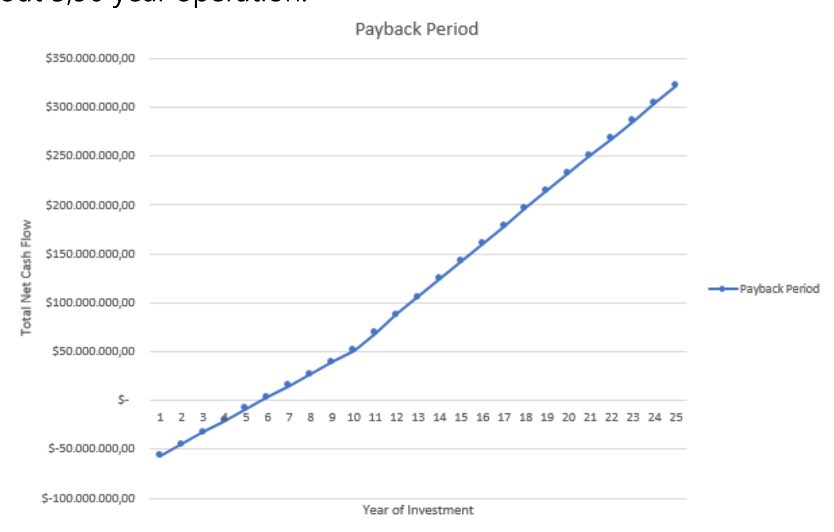
If the LNG is sold to the consuments in margin of US$3.00 per mmbtu, if the LNG is sold for US$10.25 (margin US$3.25 per mmbtu), the graphic below shows that payback period is about 6,70 year operation.



Graphic 4.5 Payback Period if LNG selling $10.00 per mmbtu

c. LNG Selling $ 10.25 (Margin $ 4.25)

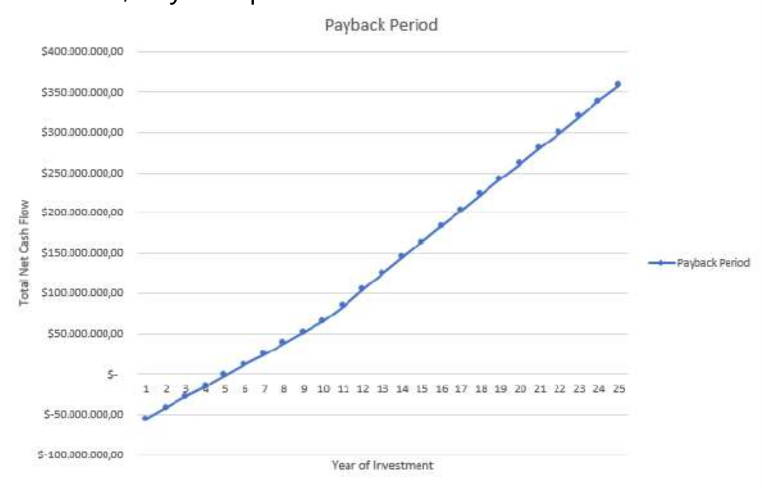
Graphic below shows the total net cash flow and year of investment if LNG is sold $10.25 (margin US$4.25 per mmbtu), it is shown that the payback period is about 5,90 year operation.



Graphic 4.6 Payback Period if LNG selling $10.25 per mmbtu

d. LNG Selling $ 10.50 (Margin $ 4.50)

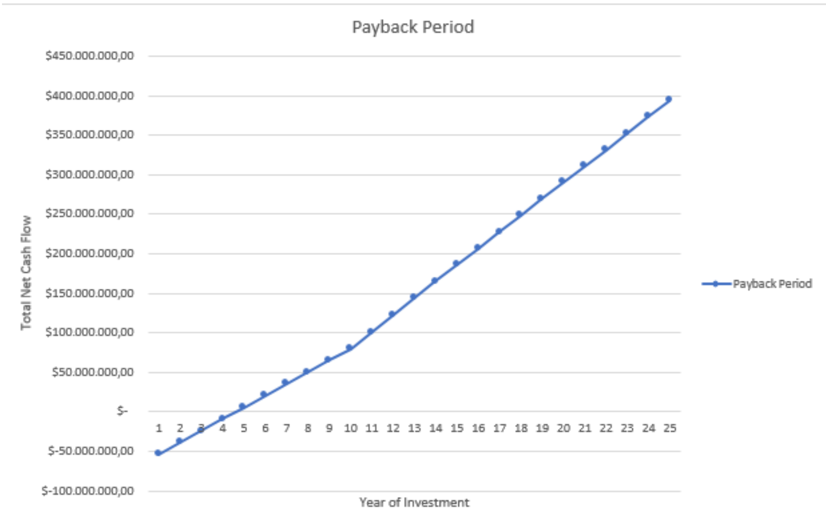
Graphic below shows the total net cash flow and year of investment if the LNG is sold for US$10.50 (margin US$3.50 per mmbtu). It is shown that the payback period is about 5,00 year operation.



Graphic 4.7 Payback Period if LNG selling $10.50 per mmbtu

e. LNG Selling $ 10.75 (Margin $ 3.75)

Graphic below shows the total net cash flow and year of investment if the LNG is sold for US$10.75 (margin US$3.75 per mmbtu). It is shown that the payback period is about 7,80 year operation.



Graphic 4.8 Payback Period if LNG selling $10.75 per mmbtu

Table 4.110 below shows the LNG selling margin to consuments. The variation is from US$9.75 per mmbtu to US$10.75 per mmbtu. All NPV and IRR in margin 9,75 to 10.75 has positive value which means that investment is feasible.

Table 4.95 Data Recapitulation in FSRU Lampung

FSRU LAMPUNG				Interest	12%
				LNG Cost per mmbtu	$6,00
LNG Selling per mmbtu	$9,75	$10,00	$10,25	$10,50	$10,75
Margin	$3,75	$4,00	$4,25	$4,50	$4,75
NPV	$23.694.612,55	$34.980.497,57	$46.266.382,60	$57.552.267,62	$68.838.152,65
IRR	17,23%	19,89%	22,68%	25,64%	28,77%
Payback period	7,80 year	6,70 year	5,90 year	5,00 year	4,80 year
Investment	Feasible	Feasible	Feasible	Feasible	Feasible

4.4 Economic Feasibility Study (Source in ARUN Gas Refinery)

4.5.1 Capital Expenditure

According to the conceptual design, the distance between Arun and West Borneo is 840 nm. So, the required SPB LNG capacity is 12000 m^3 with investment cost is US$60.000.000 and LNG tank cost is US$ 8.000.000. The total cost of capital expenditure is US$90.768.028.

4.4.2 Operational Expenditure

According to the conceptual design, bunkering cost demand for sailing to Arun is US$3.993.483, according to detail calculation of operational cost, the total cost of operational cost in the first year is US$7.813.102.

4.5.3 Investment Cost

Invstment cost is also planned for 25 years. The tax for this investment is 25% and interest is 12% per year because the investment is located in Indonesia. Loan finance is assumed to be 50% and own finance is 50%. While inflation is increasing 8% per five year. The total investment cost for 25 years is US$258.502.234,32.

4.5.4 LNG Cost

LNG cost in Arun according to the PGN data is very fluctuative in the range of $ 4.75– 6.00 per mmbtu. In this case, the cost is assumed for US$6.5 per mmbtu for giving space to the fluctuative price. So the cost for 1 m3 cargo LNG is 21,2 mmbtu x $ 7/mmbtu, then the result is US$137,80/m3. The calculation for LNG cost in 25 years is 1.247.090.000,00.

4.5.5 Depresiation

Value of asset is assumed to be depresiated for 2% linierly. So the asset will be depresiated US$-1776336,80. Total asset value is $88.816.840 and will be depresiated for 25 years with the number of asset value is US$44.408.420.

4.5.6 Revenue

LNG selling is sold for US$9,75 - US$10,75 per mmbtu. The total revenue for 25 years investment is US$2.014.350.000.

4.5.7 Cash Flow

Cash flow in mini LNG plant operation is the total of all capital expenditure, operational expenditure, tax and interest of loan finance. Table below shows cash inflow and cash outflow of mini LNG plant

Table 4.96 Net Cash Flow, Payback Period and Present Value

Year to	Year	Total Net Cash Flow	Payback Period	Present value
1	2.020	$-81.422.776	$-81.422.776	$-71.423.488
2	2.021	$7.755.994	$-73.666.782	$5.967.986
3	2.022	$7.755.994	$-65.910.788	$5.235.075
4	2.023	$7.755.994	$-58.154.794	$4.592.171
5	2.024	$7.755.994	$-51.286.374	$4.028.220
6	2.025	$6.868.420	$-44.027.070	$3.129.160
7	2.026	$7.259.304	$-36.767.765	$2.901.089
8	2.027	$7.259.304	$-29.508.461	$2.544.815
9	2.028	$7.259.304	$-22.249.157	$2.232.294
10	2.029	$7.259.304	$-14.989.853	$1.958.152
11	2.030	$15.021.921	$32.068	$3.554.447
12	2.031	$15.444.076	$15.476.143	$3.205.558
13	2.032	$15.444.076	$30.920.219	$2.811.893
14	2.033	$15.444.076	$46.364.295	$2.466.573
15	2.034	$15.444.076	$61.808.370	$2.163.661
16	2.035	$14.408.809	$76.217.180	$1.770.722
17	2.036	$14.864.737	$91.081.916	$1.602.414
18	2.037	$14.864.737	$105.946.653	$1.405.626
19	2.038	$14.864.737	$120.811.390	$1.233.006
20	2.039	$14.864.737	$135.676.126	$1.081.584
21	2.040	$14.088.732	$149.764.859	$899.228
22	2.041	$14.581.134	$164.345.993	$816.365
23	2.042	$14.581.134	$178.927.127	$716.110
24	2.043	$14.581.134	$193.508.261	$628.167
25	2.044	$14.581.134	$208.089.395	$551.023

4.5.8 PMT (Payment)

PMT, one of the financial functions, calculates the payment for a loan based on constant payments and a constant interest rate. In this investment, loan must be done in 10 years of operation. PMT formula in Microsoft Excel is PMT (rate,nper,pv).

Notes:

- Rate : Interest (percent)
- Nper : time for loan (year).
- PV : Total Loan

In this case, the loan for investment is US$49.276.705,17. So the PMT in Microsoft Excel will be PMT(12%,10, 37.404.627,17) and the PMT for one year is US$8.721.196,65 (constant in 10 years).

4.5.9 Economic Feasibility Study Arun

a. Net Present Value (NPV) approach gives project contribution toward the total value of a firm which means positive contribution from a project will directly add value to the firm or vice versa. By using the formula, Net Present Value of this project is US$ -4.092.556.

b. Internal rate return (IRR) criterion is an evaluation approach very similar to the NPV method. It also discounts the cash inflows and cash outflows of the project. By using the formula, Internal Rate Return is 11,32%.

c. Payback Period (PP) is an evaluation approach to compare the initial cash outlay with the subsequent annual cash inflows of the project in order to determine the number of years needed to recover the initial investment. There is no payback period because the Net Present Value is US$-4.092.556.

a. LNG selling US$9.75 (Margin US$3.25)

If LNG is sold to consuments in margin of US$3.25 per mmbtu, the Investment is not feasible.

b. LNG selling US$10.00 (Margin US$3.50)

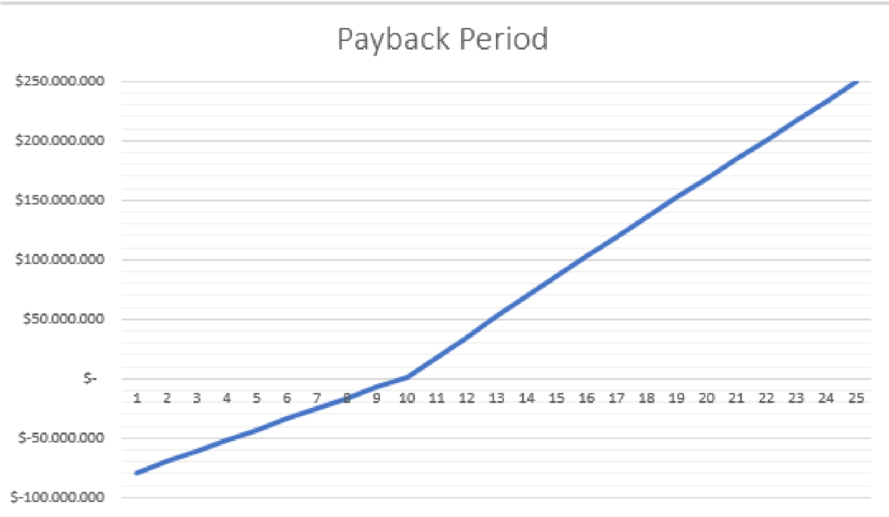
If the LNG is sold to the consuments in margin of US$3.50 per mmbtu, the Investment is not feasible.

c. LNG Selling US$10.25 (Margin US$3.75)

If the LNG is sold to the consuments in margin of US$3.75 per mmbtu, the Investment is not feasible.

d. LNG Selling US$10.50 (Margin US$4.00)

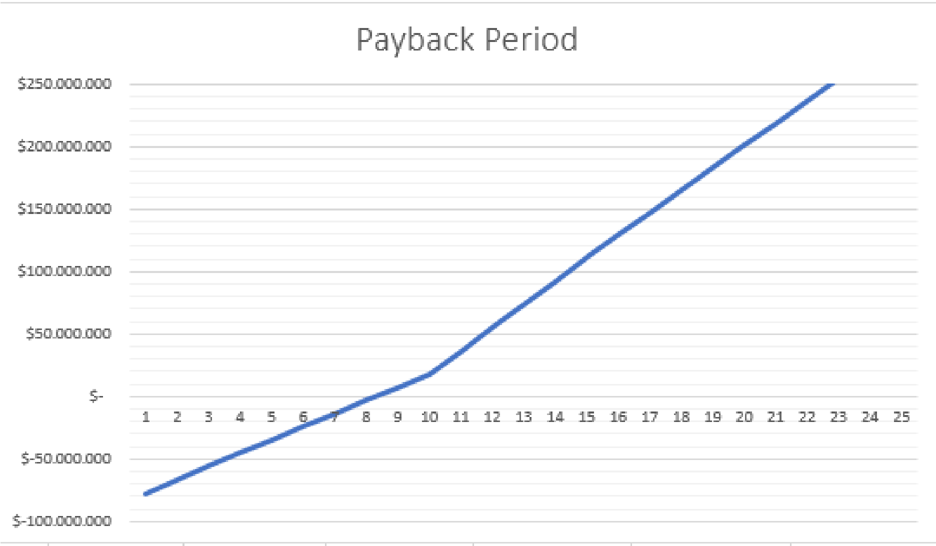
Graphic below shows the total net cash flow and year of investment if the LNG is sold for US$10.50 (margin $4.50 per mmbtu). It is shown that the payback period is about 10,00 year operation.



Graphic 4.9 Payback Period if LNG selling $10.50 per mmbtu

e. LNG Selling $ 10.75 (Margin $ 4.25)

Graphic below shows the total net cash flow and year of investment if the LNG is sold for US$10.75 (margin US$3.75 per mmbtu). It shows that the payback period is about 8,20 year operation.



Graphic 4.10 Payback Period if LNG selling $10.75 per mmbtu

Table 4.97 below is shows the LNG selling margin to consuments. The variation is from US$9.75 per mmbtu to US$10.75 per mmbtu. NPV and IRR in margin of 9,75 to 10.25 has negative value which means the investment is not feasible. Investment is feasible if the margin is set for US$4.00 per mmbtu or with the LNG selling US$10.50 per mmbtu.

Table 4.97 Data Recapitulation

ARUN GAS				Interest	12%
				LNG Cost per mmbtu	$6,50
LNG Selling	$9,75	$10,00	$10,25	$10,50	$10,75
Margin	$3,25	$3,50	$3,75	$4,00	$4,25
NPV	$-29.673.895,50	$-16.883.225,80	$-4.092.556,11	$8.698.113,59	$21.488.783,28
IRR	7,07%	9,19%	11,32%	13,47%	15,68%
PP (years)	-	-	-	10 year	8,20 year
Investment	Not Feasible	Not Feasible	Not Feasible	Feasible	Feasible

4.5.10 Economic Feasibility Study (Arun) if LNG cost is $ 6 per mmbtu

LNG price in Indonesia is very fluctuative, the price now depends on the President's decision. It is planned that President will confirm the LNG price in Indonesia for US$6 per mmbtu. So, the economic aspect will be calculated based on LNG price in Arun of US$6 per mmbtu. The result of calculation below (Table 4.109) shows that if the LNG selling is US$10.25 per mmbtu, the value of NPV will be US$322.884.177,0. The Value of IRR will be 15.94% and Payback period is 8,0 year of operation.

Table 4.98 Net Cash Flow, Payback Period and Present Value

No	Variable	Value
1	LNG Cost	$ 6 per mmbtu
2	LNG Selling	$ 10,25 per mmbtu
3	Margin	$4,25
4	Net Present Value (NPV)	$ 22.884.177
5	Internal Rate Return (IRR)	15,94%
7	Payback Period	8 year operation

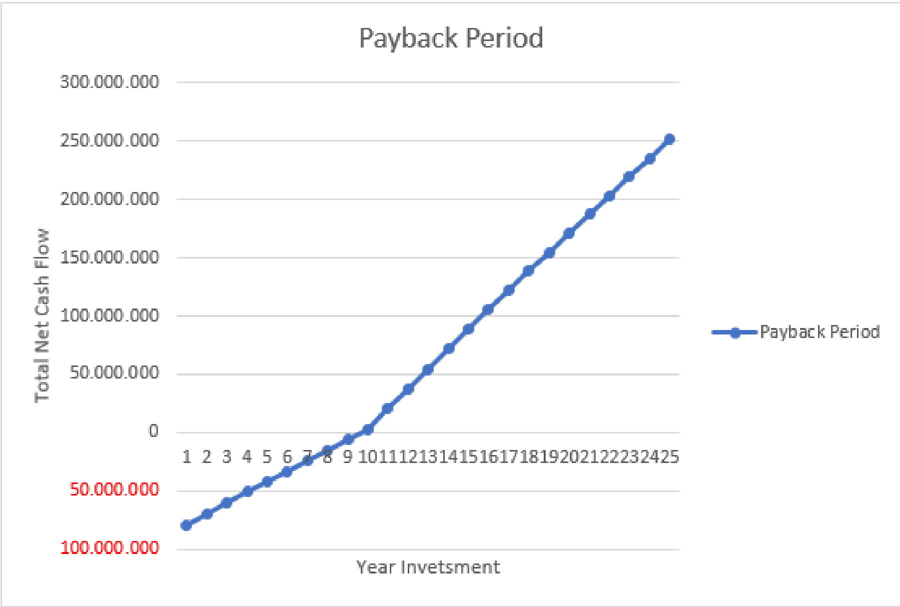
a. Payback Period

a. LNG selling US$9.75 (Margin US$3.75)

If the LNG is sold to the consuments in margin US$3.75 per mmbtu, the Investment is not feasible.

b. LNG selling US$10.00 (Margin US$4.00)

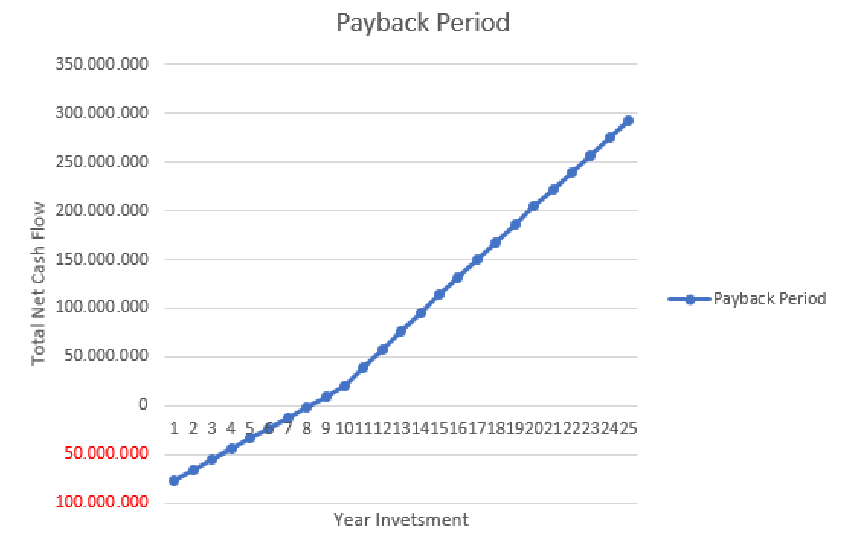
Graphic below shows the total net cash flow and year of investment if the LNG is sold US$10.50 (margin US$4.50 per mmbtu). It shows that the payback period is about 10,10 year operation.



Graphic 4.11 Payback Period if LNG selling $10.50 per mmbtu

c. LNG Selling $ 10.25 (Margin $ 4.25)

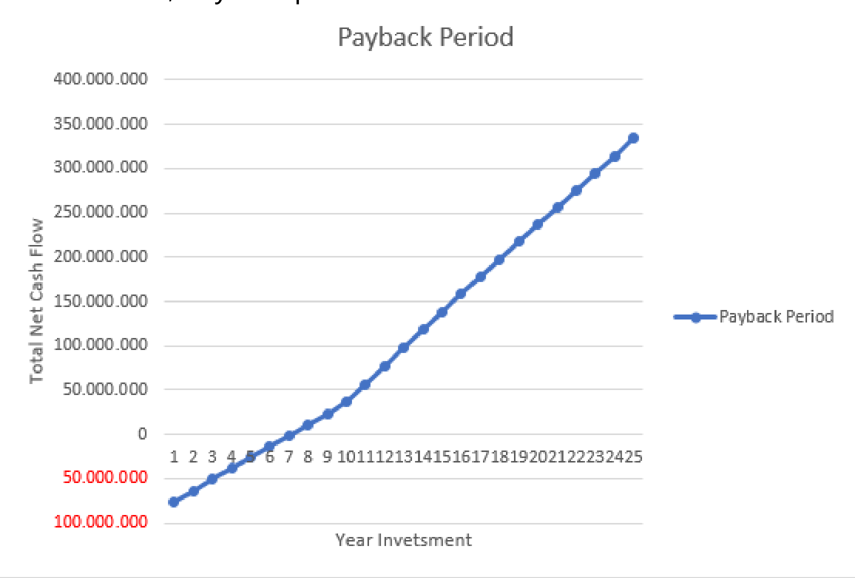
Graphic below shows the total net cash flow and year of investment if the LNG is sold for US$10.50 (margin US$4.50 per mmbtu). It shows that the payback period is about 8,40 year operation.



Graphic 4.12 Payback Period if LNG selling $10.50 per mmbtu

d. LNG Selling $ 10.50 (Margin $ 4.50)

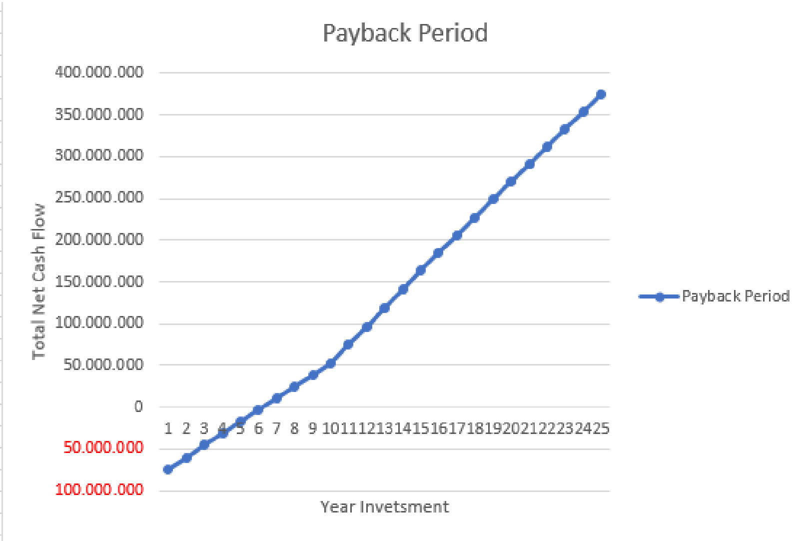
Graphic below shown the total net cash flow and year of investment if the LNG is sold for US$10.50 (margin US$4.50 per mmbtu). It shows that payback period is about 7,30 year operation.



Graphic 4. 13 Payback Period if LNG selling $10.50 per mmbtu

e. LNG Selling $ 10.75 (Margin $ 4.75)

Graphic below shows the total net cash flow and year of investment if the LNG is sold for US$10.75 (margin US$3.75 per mmbtu). It shows that the payback period is about 8,20 year operation.



Graphic 4. 14 Payback Period if LNG selling $10.75 per mmbtu

4.5.10 Data Recapitulation

Table 4.110 below shows the LNG selling margin to consuments. The variation is from US$9.75 per mmbtu to US$10.75 per mmbtu. The NPV and IRR in margin 10.00 to 10.75 has positive value which means the investment is feasible. While if margin is only US$3.75, the investment is not feasible.

Table 4.99 Data Recapitulation in Arun

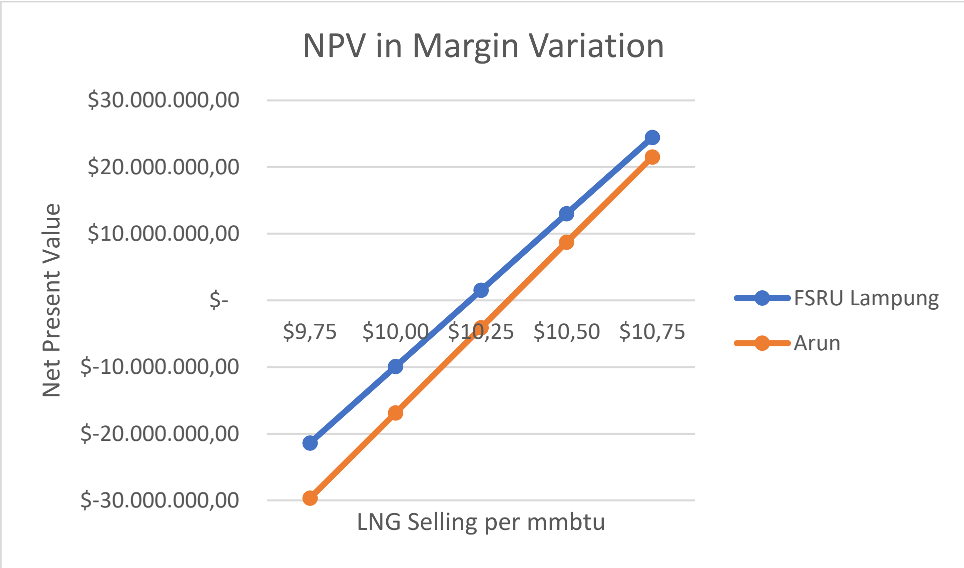
ARUN GAS				Interest	12%
				LNG Cost per mmbtu	$6,50
LNG Selling	$9,75	$10,00	$10,25	$10,50	$10,75
Margin	$3,75	$4,00	$4,25	$4,50	$4,75
NPV	$- 2.998.118,78	$9.943.029,38	$22.884.177,54	$35.825.325,71	$48.766.473,87
IRR	11,50%	13,69%	15,94%	18,26%	20,69%
Investment	Not Feasible	Feasible	Feasible	Feasible	Feasible

4.5 Economic Feasibility Study Comparison

4.6.1 Different LNG Price

1. **NPV in Margin Variation**

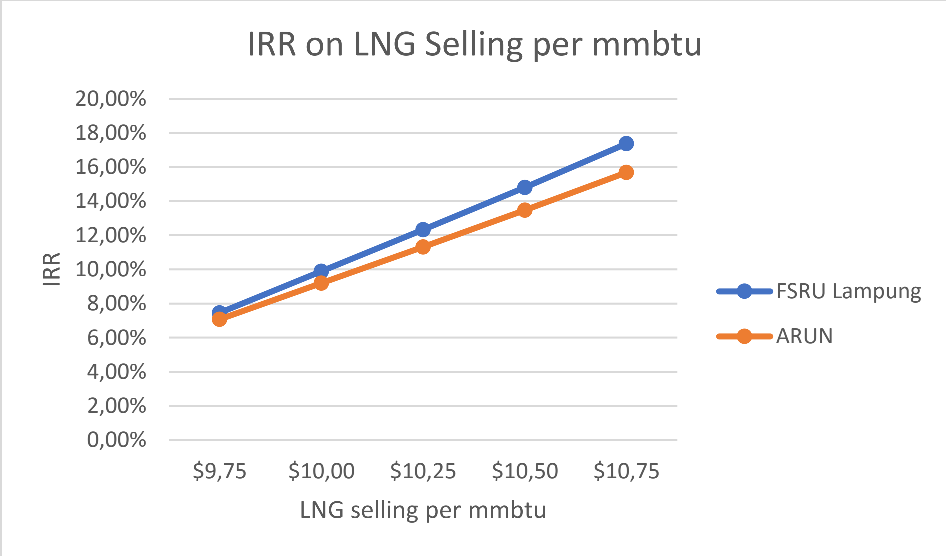
   Graphic 4.15 below shows the comparison between investment of mini LNG plant in Arun and FSRU Lampung. LNG price in FSRU Lampung is US$7 per mmbtu while LNG price in Arun is US$6.5 per mmbtu. From the graphic, it can be concluded that buying LNG in FSRU Lampung is more economics because it has higher Net Present Value (NPV) than Arun Gas Refinery. In the same price at US$10.25 per mmbtu, Investment by buying LNG in FSRU Lampung is feasible than buying LNG in Arun as investment.



Graphic 4.15 NPV in Margin Variation

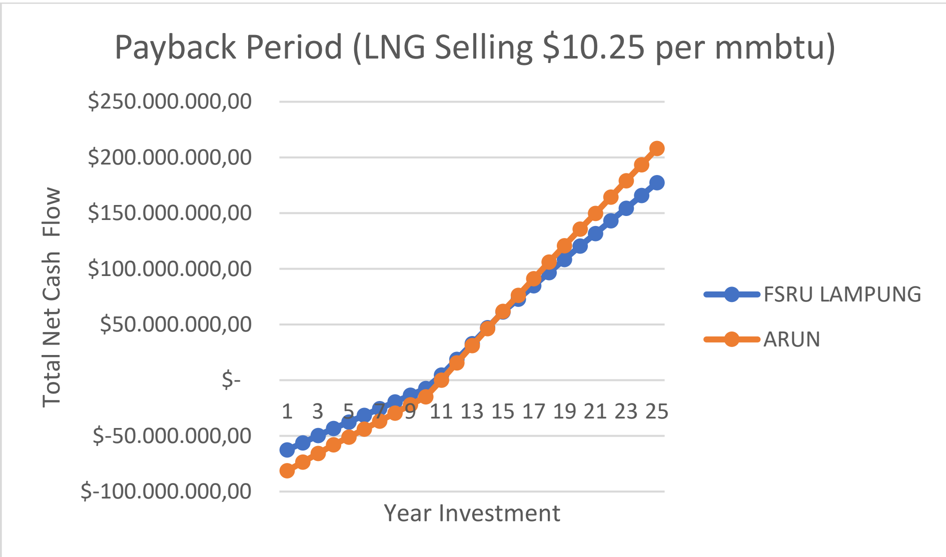
2. **Internal Rate Return (IRR) on LNG Selling per mmbtu**

   Graphic 4.16 below shows the comparison of Internal rate return (IRR) in Arun and FSRU Lampung. From the graphic, it can be concluded that FSRU Lampung has higher Internal rate return (IRR) in all margin variation. So, Investment by buying LNG in FSRU Lampung is feasible than buying LNG in Arun as investment.



Graphic 4.16 IRR in LNG Selling per mmbtu

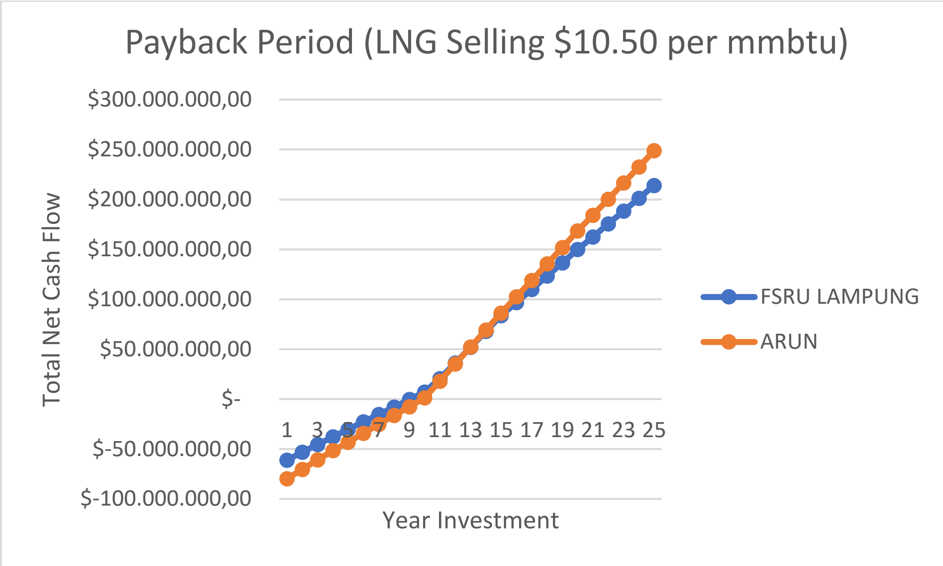
3. **Payback Period (LNG Selling $10.25 per mmbtu)**
   At the same LNG selling price, payback period of LNG in FSRU Lampung is shorter than Arun, but investment in Arun with 25 years investment has higher total net cash flow than FSRU Lampung. But in this case, Investment by buying LNG in Arun with price of LNG US$10.25 per mmbtu is not feasible.



Graphic 4.17 Payback Period (LNG Selling $10.25 per mmbtu)

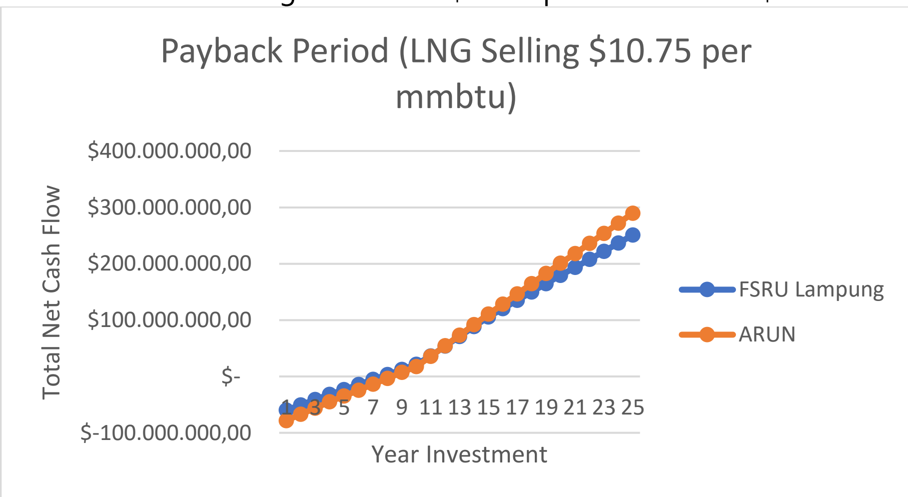
4. **Payback Period (LNG Selling $10.50 per mmbtu)**

At the same LNG selling price, payback period of buying LNG in FSRU Lampung is also shorter than Arun. However investment in Arun with 25 years investments also has higher total net cash flow than FSRU Lampung.



Graphic 4.18 Payback Period (LNG Selling $10.50 per mmbtu)

5. **Payback Period (LNG Selling $10.75 per mmbtu)**
   At the same LNG selling price, payback period of buying LNG in FSRU Lampung is also shorter than Arun. However, investment in with 25 years investments also has higher total net cash flow than FSRU Lampung. Total net cash flow of selling LNG for US$10.75 per mmbtu is US$297 million.

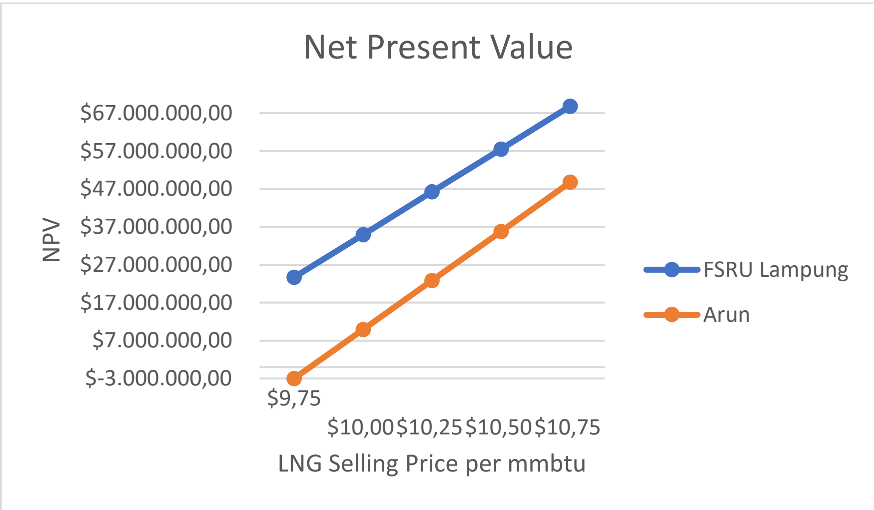


Graphic 4.19 Payback Period (LNG Selling $10.75 per mmbtu)

4.5.2 Similar LNG Price

1. **NPV in Margin Variation**

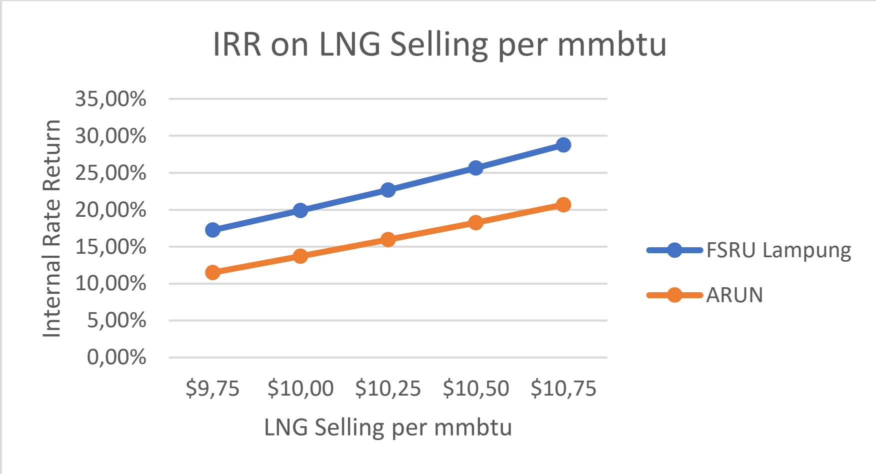
   Graphic 4.20 below shows the comparison between investment of mini LNG plant in Arun and FSRU Lampung if the LNG price is at the same rate of US$6 per mmbtu. From the graphic, it can be concluded that buying LNG in FSRU Lampung is also more economic because it has higher Net Present Value (NPV) than Arun Gas Refinery. Another reason is because operational cost will be lower as its distance only 480 nm.



Graphic 4.20 NPV in Margin Variation

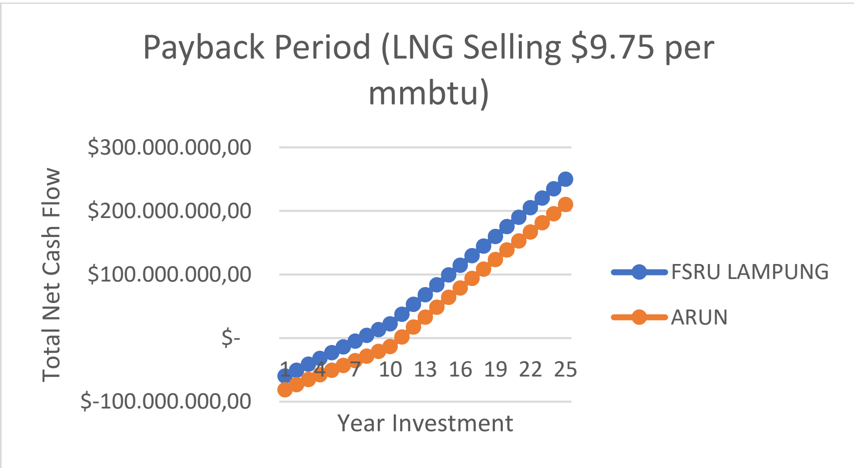
2. **Internal Rate Return (IRR) on LNG Selling per mmbtu**

   Graphic 4.20 below shows the comparison Internal rate return (IRR) in Arun and FSRU Lampung if the LNG price is at the same rate of US$6 per mmbtu. From the graphic, it can be concluded that FSRU Lampung has higher Internal rate return (IRR) in all margin variation.



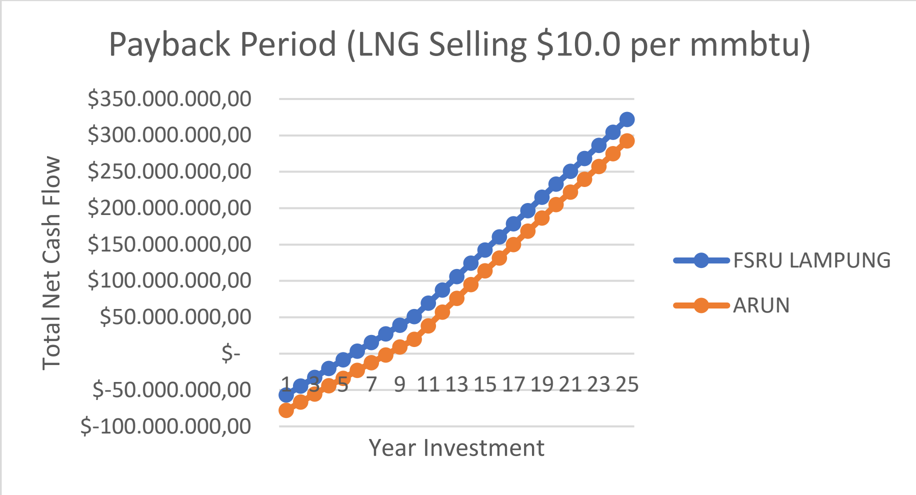
Graphic 4.21 IRR on LNG Selling per mmbtu

3. **Payback Period (LNG Selling $10.25 per mmbtu)**
   At the same LNG selling price to consumen, payback period of LNG in FSRU Lampung is shorter than Arun. Total net cash flow by buying LNG in FSRU Lampung is higher than Arun in all margin variation. This is because of the operational cost is lower as the source of LNG is nearer.



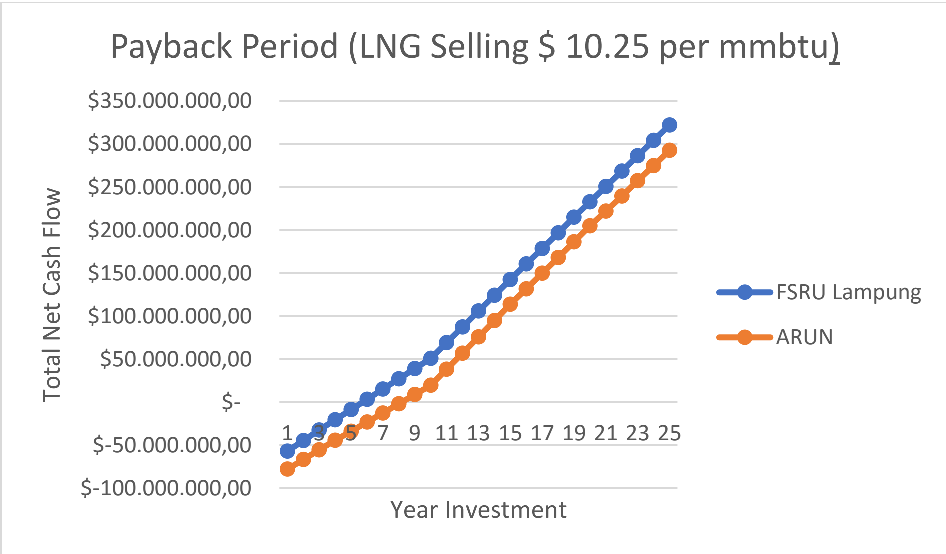
Graphic 4.22 Payback Period (LNG Selling $9.75 per mmbtu)

4. **Payback Period (LNG Selling $10.25 per mmbtu)**
   Payback period by selling LNG US$10.25 per mmbtu is shown in Graphic 4.23 below.



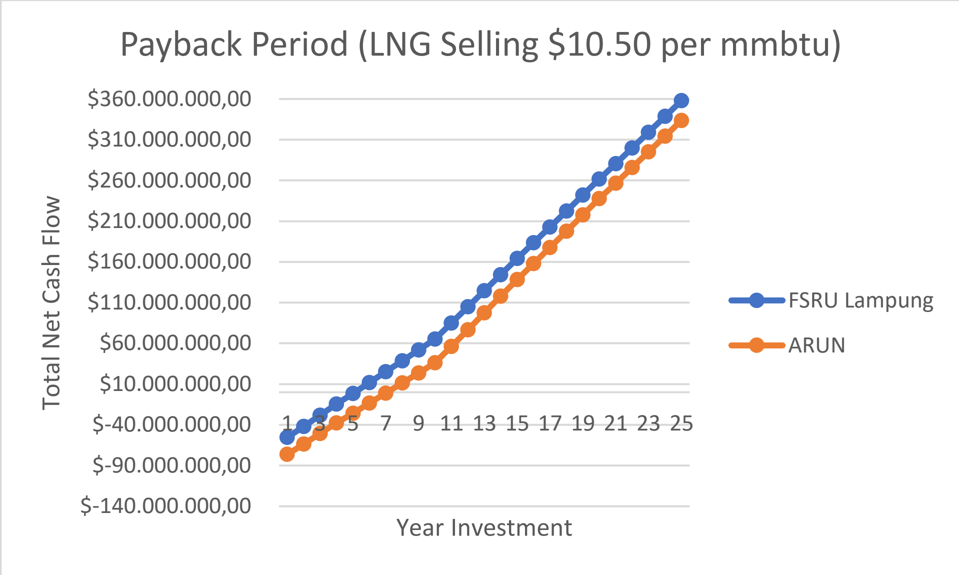
Graphic 4.23 Payback Period (LNG Selling $10.00 per mmbtu)

5. **Payback Period (LNG Selling $10.25 per mmbtu)**
   Payback period by selling for LNG US$10.25 per mmbtu is shown in graphic 4.24 below.



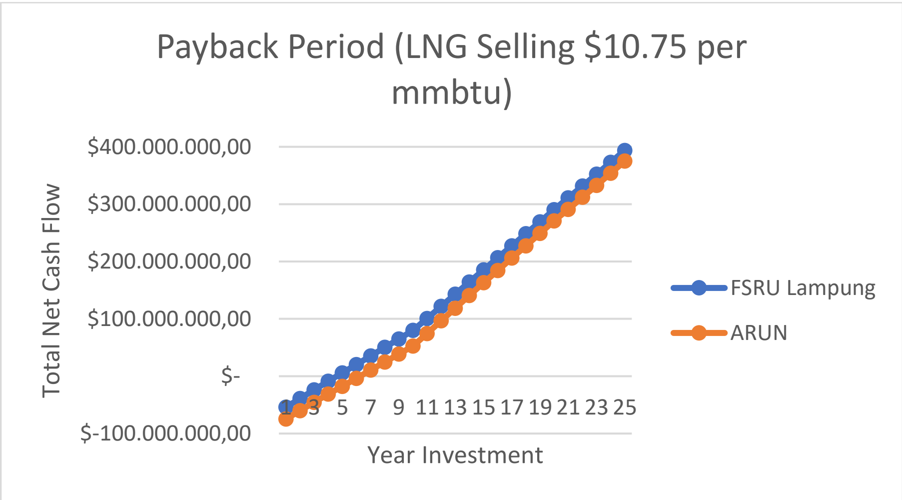
Graphic 4.24 Payback Period (LNG Selling $10.25 per mmbtu)

6. **Payback Period (LNG Selling $10.25 per mmbtu)**
   Payback period by selling LNG for US$10.25 per mmbtu is shown in Graphic 4.25 below.



Graphic 4.25 Payback Period (LNG Selling $10.50 per mmbtu)

7. **Payback Period (LNG Selling $10.25 per mmbtu)**
Payback period by selling LNG for US$10.25 per mmbtu is shown in Graphic 4.26 below.



Graphic 4.26 Payback Period (LNG Selling $10.75 per mmbtu)

CHAPTER V
CONCLUSION & SUGGESTION

5.1 Conclusion

Based on data analysis in Chapter IV entitled 'Conceptual Design of Mini LNG Supply Chain for Power Plants in West Borneo', there are three conclusions.

1. The location for building mini LNG plant for West Borneo by using Elimination and Choice Expressing Reality (Electre) method is Siantan, Regency in coordinate 0.0548460 S, 109.204387o. While the selection technology for regasification is Submerged Combustion Vaporizer (SCV). If the selection of location and vaporizer is combined and analyzed by elimination and choice expressing reality (ELECTRE), the result is using 'technology submerged combustion vaporizer in Siantan, West Borneo'. So, in ELECTRE, the result will be same if it is analyzed by separating the 'decision making process' or combining the 'decision making process'.

2. The most economical conceptual design for mini LNG plant in West Borneo with the source of LNG in FSRU Lampung is using Self Propelled LNG Barge with cargo capacity is 7500 m^3, 49 round trip per year, and 25 LNG storage tank capacity 300 m^3 per tank. The value of Investment is US$51.604.535,59. While the most economical conceptual design from source of LNG in Arun Gas Refinery is using Self Propelled Barge 12000 m^3, 31 round trip per year, and 40 LNG storage tank capacity 300 m^3 per tank. The value of Investment is US$76.960.151,37.

3. Both conceptual design is calculated in terms of economics by selling LNG in ideal price of US$10.25 per mmbtu with loan finance is 50% and Interest is 12%. The conclusion is:

a. The investment rate if the LNG price in both source is different (FSRU Lampung price is US$7 per mmbtu, Arun price is US$6.5 per mmbtu).

   Investment if the source of LNG in FSRU Lampung has Net Present Value US$1.520.574, IRR in amout of 12,33% and payback period 9,75 year of operation. While Investment if the source of LNG in Arun has Net Present Value US$-4.092.556.11, IRR in amout of 11,32. It can be concluded that the investment by buying LNG in FSRU Lampung is more feasible than Arun.

b. Investment if the LNG price in both source is same (US$6 per mmbtu)

   Investment in the source of LNG in FSRU Lampung has Net Present Value US$46.266.382,0, IRR in amout of 22,68% and payback period of 5,80 year of operation. While Investment on the source of LNG in Arun has Net Present Value US$22.884.177.54, IRR in amout of 15.94 and payback period 8,0 year of operation. It can be concluded that the investment both is feasible but FSRU Lampung has higher Net Present Value and Internal Rate Return.

5.2 Suggestion

Based on data analysis in Chapter IV entitled 'Conceptual Design of Mini LNG Supply Chain for Power Plants in West Borneo', there are three suggestions given.

1. Engineering survey for selecting location of mini LNG receiving terminal in West Borneo needs more valid data. It will be better if the quesioner is given by expert which has been working in that area especially in mobile power plants Jungkat 100 mw and PLTG Siantan.

2. LNG price data in Indonesia is very secretive and the accuration of data is also fluctuative, it will be better if the fixed cost is known.

3. This research can be continued by designing regasification system for power plants in West Borneo, and doing risk assessment of it.

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Attachment A

Quesioner Response

1. Quesioner Plant Location (Siantan Regency)

Responden	Siantan Regency					
	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost
Resp 1	5	5	3	5	3	3
Resp 2	3	3	4	5	4	3
Resp 3	2	2	4	4	2	2
Resp 4	5	5	5	5	5	4
Resp 5	3	3	3	3	3	3
Resp 6	2	3	3	4	4	2
Resp 7	3	3	4	4	4	3
Resp 8	2	2	4	4	4	4
Resp 9	2	2	3	2	1	3
Resp 10	4	5	3	5	4	2
Resp 11	4	3	3	3	4	3
Resp 12	5	3	4	4	4	4
Resp 13	2	3	2	2	3	3
Resp 14	4	4	2	3	3	2
Resp 15	3	2	3	4	3	3
Resp 16	5	5	5	5	5	5
Resp 17	2	4	4	4	4	4
Resp 18	5	4	3	3	4	4
Resp 19	3	4	3	4	1	3
Resp 20	4	3	4	3	3	3
Resp 21	1	1	1	1	1	1
Resp 22	3	4	3	4	5	4
Resp 23	4	3	3	2	2	3
Resp 24	5	5	4	5	2	4
Resp 25	2	1	4	2	2	5
Resp 26	4	5	3	3	4	1
Resp 27	3	3	4	4	3	4
Resp 28	5	5	4	4	4	4
Resp 29	4	3	4	3	4	3
Resp 30	4	3	4	4	3	2
Modus	4	3	4	4	4	3

Siantan Regency						
Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
5	3	3	3	2	4	4
4	5	4	4	4	4	4
1	4	4	4	4	3	3
5	5	5	5	5	5	3
3	3	3	3	3	3	4
3	4	2	3	4	3	3
5	4	3	5	4	4	2
5	5	4	4	4	4	3
2	1	1	4	3	4	4
4	5	3	3	1	4	3
3	3	3	4	3	3	3
3	4	4	4	4	4	4
4	4	4	5	3	3	3
4	2	2	3	3	3	2
3	3	3	2	3	4	3
5	5	5	5	4	4	4
4	4	4	4	4	4	4
3	4	4	5	4	3	4
2	4	4	3	3	3	4
4	4	4	3	2	3	4
1	1	1	1	1	1	1
5	4	3	5	4	4	3
4	4	3	3	4	4	4
4	2	2	4	4	4	5
2	4	1	3	3	4	3
3	3	4	4	3	3	3
2	2	3	4	3	4	5
4	4	3	4	5	3	3
5	5	5	5	3	5	5
4	3	3	3	4	3	4
4	4	3	4	4	4	4

2. Quesioner Plant Location (Pontianak City)

Responden	Pontianak City					
	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost
Resp 1	2	2	3	5	3	2
Resp 2	2	2	3	4	3	2
Resp 3	2	4	4	4	4	3
Resp 4	5	5	5	5	5	3
Resp 5	3	3	3	3	3	3
Resp 6	3	3	3	4	4	4
Resp 7	4	3	4	4	4	2
Resp 8	2	3	3	3	3	3
Resp 9	2	4	5	4	5	4
Resp 10	3	5	4	5	4	2
Resp 11	2	2	2	3	3	3
Resp 12	5	4	5	4	5	4
Resp 13	2	2	3	3	4	2
Resp 14	3	2	3	3	4	4
Resp 15	2	3	2	3	3	2
Resp 16	5	5	5	5	5	5
Resp 17	2	4	4	4	4	4
Resp 18	4	3	5	3	3	4
Resp 19	2	4	3	3	2	4
Resp 20	3	3	3	3	3	4
Resp 21	1	1	3	1	1	3
Resp 22	4	4	5	4	5	4
Resp 23	3	3	3	2	2	2
Resp 24	2	2	4	5	3	2
Resp 25	2	2	4	2	1	1
Resp 26	2	3	4	3	3	2
Resp 27	2	2	4	4	3	1
Resp 28	5	4	4	4	4	4
Resp 29	3	3	4	4	4	4
Resp 30	5	5	4	4	3	4
Modus	2	3	3	4	3	4

Pontianak City						
Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
2	4	4	5	4	2	4
4	3	3	5	4	3	4
1	4	4	4	4	4	2
5	5	5	5	5	5	4
3	3	3	3	3	3	3
3	4	2	4	4	3	3
3	4	4	3	4	3	4
2	4	5	5	4	4	2
4	5	4	5	5	4	2
4	5	5	3	2	3	2
3	2	3	3	2	2	3
4	4	4	5	4	4	4
4	4	5	5	2	3	4
3	4	3	4	5	4	3
4	4	4	4	3	3	3
5	5	5	5	4	5	4
4	4	4	4	4	4	4
5	3	2	5	3	2	4
1	4	3	3	3	3	4
3	3	3	3	2	3	4
3	3	3	3	1	3	1
5	4	5	4	4	4	4
3	5	5	4	4	3	3
2	4	4	4	2	3	5
3	4	4	5	3	4	3
2	4	5	2	4	3	3
1	5	5	5	4	3	4
4	4	3	4	4	4	4
5	5	5	5	4	4	4
3	4	4	4	4	2	4
3	4	4	5	4	3	4

3. Quesioner Location Plant (Offshore Mini FSRU)

Responden	Offshore (Mini FSRU)					
	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost
Resp 1	5	5	1	2	5	3
Resp 2	1	1	3	4	1	3
Resp 3	5	2	3	3	2	4
Resp 4	5	5	5	5	5	3
Resp 5	3	3	3	3	3	2
Resp 6	1	1	4	3	1	3
Resp 7	1	2	4	5	5	4
Resp 8	5	5	5	1	2	3
Resp 9	5	4	5	5	4	2
Resp 10	3	4	5	5	3	3
Resp 11	2	5	4	2	4	4
Resp 12	4	4	4	4	4	2
Resp 13	4	3	2	2	4	3
Resp 14	4	5	3	1	3	4
Resp 15	2	2	2	1	3	2
Resp 16	5	5	5	5	5	5
Resp 17	2	4	4	4	4	4
Resp 18	5	4	5	2	5	4
Resp 19	5	4	2	2	5	4
Resp 20	5	5	2	2	2	4
Resp 21	5	5	5	1	5	3
Resp 22	5	5	4	4	5	4
Resp 23	5	4	4	3	3	2
Resp 24	5	5	2	1	3	4
Resp 25	4	1	3	2	1	1
Resp 26	3	2	2	2	2	2
Resp 27	5	5	2	1	4	4
Resp 28	5	5	5	5	3	5
Resp 29	5	5	5	3	3	2
Resp 30	5	5	5	4	5	5
Modus	5	5	5	2	5	4

Offshore (Mini FSRU)						
Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
2	1	5	5	2	1	2
5	5	5	3	4	2	5
2	2	4	4	2	2	2
5	5	5	5	5	3	5
3	3	3	3	3	2	3
4	4	3	3	4	2	4
5	5	4	2	5	2	5
4	2	4	5	3	1	4
3	2	5	4	3	3	3
5	5	3	5	1	3	5
4	1	4	3	2	3	4
4	4	4	4	4	2	4
2	2	3	2	2	2	2
4	4	4	1	1	3	4
3	3	3	3	3	5	3
5	5	5	4	5	5	5
4	4	4	4	4	4	4
4	3	5	3	3	5	4
2	3	4	3	2	2	2
4	3	3	5	3	2	4
5	3	5	5	3	3	5
5	4	5	4	4	4	5
2	3	3	4	3	4	2
4	4	4	4	1	1	4
3	2	3	3	2	3	3
3	2	3	3	3	3	3
2	2	2	4	2	2	2
4	3	4	5	3	3	4
3	3	4	4	3	4	3
3	3	4	3	5	5	3
4	3	4	3	3	2	4

4. Quesioner LNG Vaporizer (Ambient Air Vaporizer)

Responden	Ambient Air Vaporizer						
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load
Resp 1	3	4	3	2	5	2	3
Resp 2	2	2	2	2	1	3	3
Resp 3	4	4	4	3	4	4	2
Resp 4	5	5	5	3	5	5	1
Resp 5	3	3	3	3	3	3	3
Resp 6	3	2	3	3	4	2	2
Resp 7	5	4	5	4	3	4	3
Resp 8	4	5	5	4	5	3	4
Resp 9	3	3	3	4	3	3	3
Resp 10	2	5	5	5	5	5	5
Resp 11	4	4	4	3	3	4	2
Resp 12	4	4	4	3	4	4	4
Resp 13	3	4	2	5	4	3	3
Resp 14	3	4	2	3	4	3	3
Resp 15	2	3	3	2	2	3	3
Resp 16	5	5	5	5	5	5	5
Resp 17	4	4	4	4	4	4	4
Resp 18	4	3	4	5	3	4	3
Resp 19	3	3	4	2	2	2	3
Resp 20	4	4	4	4	4	3	3
Resp 21	5	5	1	3	1	5	3
Resp 22	3	3	3	4	4	4	3
Resp 23	4	4	4	4	4	3	2
Resp 24	3	4	4	2	5	2	2
Resp 25	5	5	5	5	4	5	4
Resp 26	3	3	3	3	3	3	3
Resp 27	5	5	4	5	5	4	2
Resp 28	5	5	5	4	3	3	3
Resp 29	4	4	5	5	5	3	3
Resp 30	4	4	3	3	4	5	4
Modus	3	4	4	3	4	3	3

Ambient Air Vaporizer						
Equipment Complexit y	Environmen t Factor	Area Geographi c	Polutio n	Ease of Operationa l	ease of maintenanc e	safety Operationa l
4	2	2	5	5	4	5
3	1	3	1	4	3	4
4	4	4	4	4	3	4
5	5	5	1	1	1	3
3	3	3	3	3	3	3
3	3	4	2	2	2	4
4	5	4	4	4	3	4
4	4	5	5	5	4	4
4	3	4	3	3	3	3
5	5	5	5	5	5	5
4	2	3	4	4	4	4
4	5	5	4	4	4	4
3	4	4	2	2	4	3
3	3	3	2	2	2	3
3	2	3	3	3	3	3
5	5	4	3	3	3	5
4	4	4	4	4	4	4
5	4	5	3	4	2	4
4	1	1	1	4	4	3
4	4	4	4	4	4	4
5	1	1	5	5	5	3
4	3	3	4	4	4	4
5	3	3	5	4	4	4
4	2	2	5	4	5	4
5	2	4	5	5	5	5
3	4	4	4	3	3	3
5	2	4	4	4	4	5
4	3	4	3	5	4	5
5	5	5	5	3	5	4
4	4	4	4	4	4	4
4	4	4	4	4	4	4

5. Quesioner LNG Vaporizer (Intermediate Fluid Vaporizer)

Responden	Intermediate Fluid Vaporizer						
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load
Resp 1	3	4	3	4	1	1	3
Resp 2	4	4	4	5	5	3	4
Resp 3	2	2	2	4	3	3	4
Resp 4	3	3	3	5	5	5	5
Resp 5	3	3	3	3	3	3	3
Resp 6	4	3	3	4	3	3	4
Resp 7	4	3	4	3	4	4	3
Resp 8	5	4	2	5	3	3	4
Resp 9	1	3	3	3	3	3	4
Resp 10	3	3	3	3	3	3	3
Resp 11	3	4	3	5	5	5	5
Resp 12	4	4	4	4	4	4	4
Resp 13	2	2	2	4	3	2	2
Resp 14	3	3	2	4	3	3	3
Resp 15	3	3	3	3	3	2	3
Resp 16	5	5	5	5	5	5	5
Resp 17	4	4	4	4	4	4	4
Resp 18	4	5	5	4	3	4	5
Resp 19	2	2	3	4	4	3	4
Resp 20	2	2	2	3	3	3	4
Resp 21	3	3	1	5	5	5	5
Resp 22	4	4	4	3	3	3	4
Resp 23	2	3	3	4	4	3	4
Resp 24	3	2	3	2	2	2	3
Resp 25	3	3	4	4	5	3	5
Resp 26	3	3	3	3	3	3	3
Resp 27	2	3	3	3	4	3	5
Resp 28	4	4	4	5	4	4	4
Resp 29	4	4	4	4	4	4	4
Resp 30	4	4	4	4	4	4	3
Modus	3	3	3	4	3	3	4

Intermediate Fluid Vaporizer						
Equipment Complexity	Environment Factor	Area Geographic	Polution	Ease of Operational	ease of maintenance	safety Operational
2	5	2	5	4	4	2
2	4	4	1	3	3	3
4	3	3	3	2	2	4
3	3	3	5	5	5	3
3	3	3	3	3	3	3
2	4	3	2	3	3	4
4	3	3	4	4	3	4
1	1	3	2	3	1	3
3	5	3	3	3	3	3
3	3	3	3	3	3	4
5	5	5	5	5	3	4
4	4	4	4	4	4	4
3	4	2	3	2	2	4
4	3	5	2	3	3	4
3	4	3	3	3	2	3
4	5	3	3	5	5	5
4	4	4	4	4	4	4
4	3	4	5	4	4	5
2	4	4	4	2	3	3
3	3	2	3	3	3	3
1	5	5	5	3	3	5
3	3	3	3	3	3	3
3	3	2	3	3	3	3
2	5	5	5	3	3	3
1	5	5	3	5	4	5
3	4	4	4	3	3	3
3	4	4	3	4	2	3
3	4	5	4	4	3	3
5	5	5	5	5	4	5
2	4	2	3	3	3	4
3	4	3	3	3	3	3

6. Quesioner LNG Vaporizer (Open Rack Vaporizer)

Responden	Open Rack Vaporizer						
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load
Resp 1	5	5	1	4	5	5	3
Resp 2	1	1	3	4	4	3	4
Resp 3	4	4	2	4	5	4	4
Resp 4	5	3	5	3	3	5	1
Resp 5	3	3	3	3	3	3	3
Resp 6	3	3	3	4	3	3	4
Resp 7	4	3	4	3	4	4	3
Resp 8	3	4	4	5	3	3	2
Resp 9	4	5	2	2	3	2	2
Resp 10	2	2	2	2	2	2	2
Resp 11	3	3	3	3	3	3	3
Resp 12	4	4	4	4	4	4	4
Resp 13	5	4	4	4	4	5	4
Resp 14	4	3	3	3	3	3	3
Resp 15	3	3	3	3	2	4	3
Resp 16	5	5	5	4	5	5	5
Resp 17	4	4	4	4	4	4	4
Resp 18	5	4	4	4	2	3	4
Resp 19	3	4	3	4	5	3	4
Resp 20	3	3	3	3	3	3	3
Resp 21	1	3	3	5	5	5	5
Resp 22	4	5	4	4	4	4	3
Resp 23	2	2	3	4	4	3	4
Resp 24	4	5	2	5	4	3	3
Resp 25	3	4	2	5	5	5	5
Resp 26	3	3	3	3	3	3	3
Resp 27	4	4	4	5	4	4	4
Resp 28	5	5	5	5	5	5	5
Resp 29	4	4	4	4	4	4	5
Resp 30	3	4	5	4	3	4	5
Modus	4	4	3	4	4	3	3

Open Rack Vaporizer						
Equipment Complexity	Environment Factor	Area Geographic	Polution	Ease of Operational	ease of maintenance	safety Operational
5	1	1	5	4	1	2
3	3	4	2	4	3	4
4	5	4	4	4	4	4
5	5	5	1	3	3	3
3	3	3	3	3	3	3
2	4	2	3	3	3	4
3	3	4	3	4	3	4
3	1	2	3	4	4	3
3	5	4	3	5	1	3
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	3	3	4	3	4	4
4	4	3	4	4	3	5
3	2	3	3	1	4	4
4	2	2	2	3	3	3
5	5	4	3	4	5	5
4	4	4	4	4	4	4
5	2	5	3	4	3	4
4	5	4	5	3	3	3
3	3	3	4	4	3	3
3	1	1	3	3	3	3
4	4	4	4	4	4	3
4	4	2	4	4	4	4
5	4	3	5	5	1	4
3	5	5	5	5	3	5
3	4	4	4	3	3	3
4	2	3	4	3	4	4
5	5	5	5	5	5	5
5	5	5	5	5	5	5
4	4	3	4	4	5	5
3	5	4	4	4	3	4

7. Quesioner LNG Vaporizer (Submerged Combustion Vaporizer)

Responden	Submerged Combustion Vaporizer						
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load
Resp 1	2	2	3	3	5	4	5
Resp 2	3	3	2	3	3	3	3
Resp 3	1	1	2	4	2	2	2
Resp 4	5	5	5	1	5	5	5
Resp 5	3	3	3	3	3	3	3
Resp 6	3	3	3	3	2	3	4
Resp 7	4	4	3	4	4	4	3
Resp 8	2	3	4	5	4	4	4
Resp 9	1	2	2	2	4	3	4
Resp 10	2	2	2	2	2	2	2
Resp 11	3	3	3	4	3	3	3
Resp 12	4	4	4	4	4	4	4
Resp 13	3	2	2	4	3	3	3
Resp 14	3	2	4	3	3	4	4
Resp 15	2	3	2	5	5	3	3
Resp 16	5	5	5	5	4	5	5
Resp 17	4	4	4	4	4	4	4
Resp 18	4	2	4	4	5	4	4
Resp 19	3	3	3	3	2	3	2
Resp 20	2	2	2	3	2	3	4
Resp 21	5	5	3	5	5	3	3
Resp 22	3	3	3	4	4	3	3
Resp 23	2	2	2	4	4	3	5
Resp 24	3	2	4	4	5	4	4
Resp 25	3	3	2	4	5	4	5
Resp 26	3	3	3	3	3	3	3
Resp 27	2	3	3	4	4	3	5
Resp 28	3	3	3	4	3	3	3
Resp 29	4	4	5	5	5	4	4
Resp 30	4	4	4	4	4	4	4
Modus	3	3	3	4	4	3	4

Submerged Combustion Vaporizer						
Equipment Complexity	Environment Factor	Area Geographic	Polution	Ease of Operational	ease of maintenance	safety Operational
3	3	3	2	4	4	4
3	3	3	3	3	3	3
2	3	3	2	2	2	2
4	5	5	1	1	1	3
3	3	3	3	3	3	3
3	2	3	5	3	3	3
3	3	4	4	3	4	3
3	1	1	1	5	5	4
4	3	3	3	2	2	5
2	2	2	2	2	2	2
3	5	3	4	3	3	4
4	4	4	4	4	4	4
4	4	4	1	3	2	4
2	3	4	4	2	1	3
3	4	4	3	3	2	2
5	3	3	3	5	5	5
4	4	4	4	4	4	4
3	4	3	5	4	3	4
3	3	2	1	2	2	4
2	2	3	3	2	2	3
1	1	1	1	5	3	1
4	3	4	3	3	4	4
3	3	4	2	4	3	3
1	5	5	1	3	3	4
1	5	5	2	3	2	2
3	4	4	4	3	3	3
2	5	4	1	3	3	3
2	2	3	2	3	3	5
4	5	5	5	4	4	5
4	4	4	4	4	4	4
3	3	3	3	3	3	4

Attachment B

Quesioner Tools

KUISIONER PENENTUAN LOKASI & TEKNOLOGI REGASIFICATION PLANT

* Required

IDENTITAS RESPONDEN

NAMA *

Your answer

PENDIDIKAN TERAKHIR *

Your answer

PEKERJAAN *

Your answer

JABATAN *

Your answer

ALAMAT EMAIL *

Your answer

NO. HP *

Your answer

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QUESTIONS RESPONSES 36

Section 1 of 13

KUISIONER PENENTUAN LOKASI & TEKNOLOGI REGASIFICATION PLANT

PETUNJUK PENGISIAN KUISIONER

1. Angket di bawah merupakan kuisioner untuk menunjang tugas akhir mahasiswa dengan nama Antonny Suheri NRP 4213101007 dengan judul "conceptual design of mini LNG supply chain for Gas Power Plants in West Borneo "sebagai mahasiswa di departemen Teknik Sistem Perkapalan ITS Surabaya

2. Terdapat dua kuisioner yang perlu responden respon yaitu,
a. Kuisioner penentuan lokasi Infrastruktur mini LNG Regasification Plant yang tepat untuk wilayah kalimantan barat
b. Kuisioner Teknologi LNG Vaporizer yang tepat untuk wilayah Kalimantan barat

3. Terdapat dua nilai kuisioner yang akan responden diberikan yaitu,
a. Nilai Kualitas pada setiap kriteria
b. Nilai pembobotan pada setiap kriteria

4. Berikan jawaban responden dengan cara menekan angka yang mewakili skala kualitas sesuai dengan analisis responden pada lembar jawaban yang tersedia dengan ketentuan sebagai berikut:

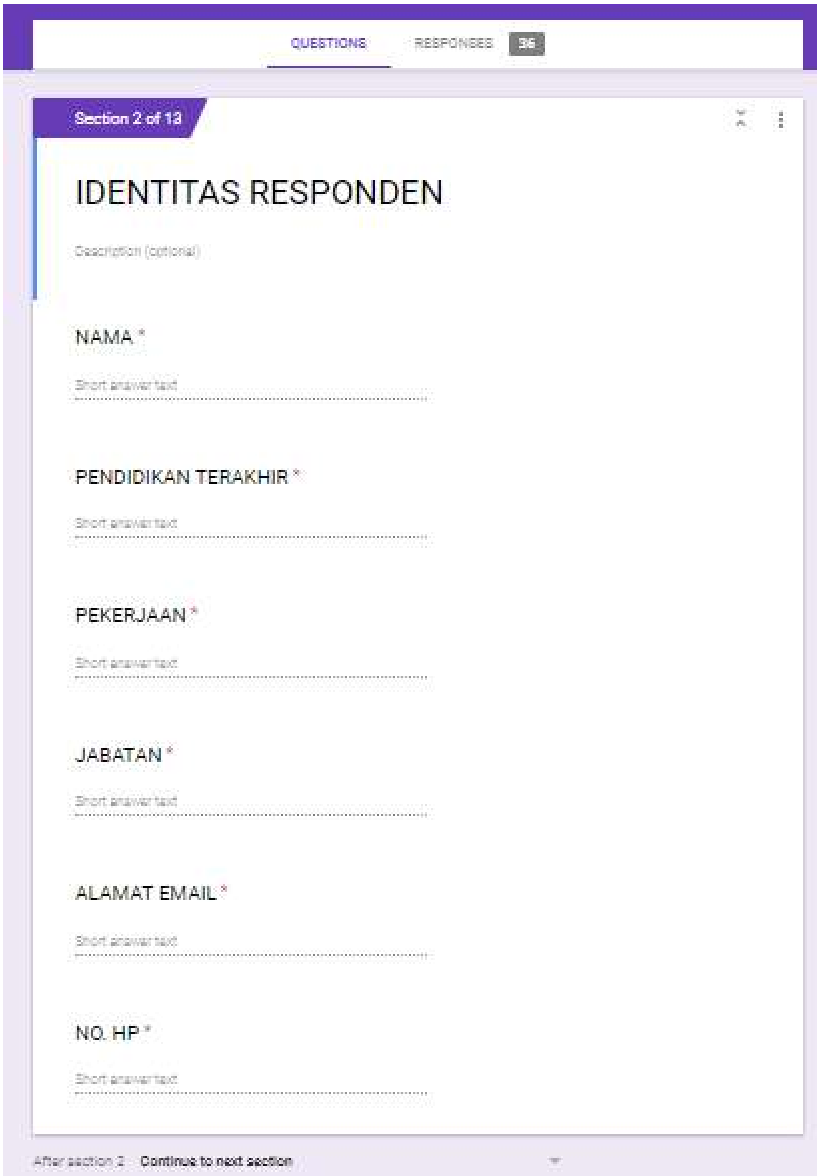
Nilai	Kualitatif
1	Sangat buruk
2	Buruk
3	Normal
4	Baik
5	Sangat baik

5. Kuisioner yang telah direspon akan menjadi data tugas akhir yang akan dianalisis di Departemen Teknik Sistem Perkapalan ITS Surabaya. Selamat mengerjakan dan terima kasih.

Hormat Saya,

Antonny Suheri
42131010007

After section 1 Continue to next section



QUESTIONS RESPONSES 36

Section 2 of 13

IDENTITAS RESPONDEN

Description (optional)

NAMA *

Short answer text

PENDIDIKAN TERAKHIR *

Short answer text

PEKERJAAN *

Short answer text

JABATAN *

Short answer text

ALAMAT EMAIL *

Short answer text

NO. HP *

Short answer text

After section 2 Continue to next section

Section 3 of 13

DESKRIPSI

Pada Penelitian berikut ini akan mendesain konseptual rantai pasok LNG untuk pembangkit gas di wilayah kalimantan barat pada sistem khatulistiwa. Pada sistem ini terdapat dua pembangkit gas yaitu, PLTG MPP Jungkat 100 MW yang berlokasi di Kabupaten Siantan dan PLTG Siantan 30 MW yang berlokasi di Kota Pontianak. Lalu direncanakan akan dibangun satu buah infrastuktur mini LNG regasification plant untuk memasok gas pada dua pembangkit gas ini pada tiga alternatif lokasi yang telah ditentukan di Kalilmantan Barat yaitu: Kabupaten Siantan, Kota Pontianak, Offshore dengan Mini FSRU.

Image title

After section 3 Continue to next section

Section 4 of 13

Kabupaten Siantan

Kabupaten Siantan berlokasi di koordinat 0.0548460 S, 109.204387o yang terletak di utara kota pontlanak kabupaten ini terdiri dari 6 desa dan kecamatan dan dialiri sungai kapuas dengan rata-rata kedalaman 6 m.

Opsi 1 : Kabupaten Siantan

Section 5 of 13

Kota Pontianak

Pontianak terletak di kordinat 0.0048220 S, 109.3049260 E dan memiliki area seluas 107,82 km2. Kota ini juga dialiri sungai kapuas dengan rata-rata kedalaman 7 m.

Opsi 2 : Kota Pontianak

Offshore (Mini FSRU)

Fasilitas offshore untuk pembangunan mini FSRU berada di koordinat 0.072853 S, 108.965844o E yang terdapat pada laut cina selatan dan 18 km ke barat dari jungkat

Opsi 3 : Offshore (Mini FSRU)

Biaya Persiapan Lahan *

Biaya persiapan lahan adalah biaya yang dibutuhkan untuk membeli lahan untuk membangun Infrastuktur mini LNG pada lahan tersebut.

	1	2	3	4	5	
sangat buruk	○	○	○	○	○	sangat baik

Biaya Pengerukan *

Biaya Pengerukan adalah biaya yang dikeluarkan untuk mengeruk lahan sehingga pada pembangunan Infrastruktur mini LNG dapat didesain dengan baik.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Biaya Operasional *

Biaya Operasional adalah biaya yang digunakan untuk mengoperasikan plant sitting.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Biaya Kapital *

Biaya Kapital adalah biaya yang dikeluarkan untuk membeli fasilitas plant sitting.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Biaya Perizinan *

Biaya yang dikeluarkan untuk mengurus perizinan pada lokasi plant sitting.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Mahal

Biaya Berthing Facility *

Biaya yang dikeluarkan untuk fasilitas sandar kapal untuk offloading.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Keamanan dan Keselamatan *

Merupakan tingkat keselamatan dan Keamanan lokasi plant sitting.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Akses Distribusi Pembangunan *

Merupakan tingkat kemudahan akses untuk mendistribusikan kebutuhan material untuk pembangunan pada daerah tersebut.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Akses Distribusi untuk Publik/Crew *

Merupakan tingkat kemudahan akses untuk karyawan/crew yang bekerja di lokasi tersebut.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Potensi Pembangunan Bisnis *

Merupakan tingkat potensi bisnis pada lokasi plant sitting daerah tersebut.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Periode Pembangunan *

Merupakan tingkat waktu dalam pembangunan infrastruktur mini LNG pada daerah tersebut.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Jarak ke Pembangkit *

Merupakan tingkat jarak yang dibutuhkan dari infrasturktur mini LNG ke pembangkit yang dituju.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Kompleksitas Peralatan *

Merupakan tingkat kesederhanaan peralatan yang dibutuhkan untuk menunjang operasi pada plant sitting.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

After section 4 Continue to next section

Section 7 of 13

KUISIONER PEMBOBOTAN

Skala Likert Nilai Qualitatif

1 Tingkat Kepentingan Sedikit Penting
3 Tingkat Kepentingan Sedang
5 Tingkat Kepentingan Penting
7 Tingkat Kepentingan Sangat Penting
9 Tingkat Kepentingan Mutlak Penting
2,4,6,8 Nilai Tengah dari masing-masing nilai Qualitatif

Biaya Persiapan Lahan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Biaya Pengerukan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Biaya operasional *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Biaya Kapital *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Biaya Perizinan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Biaya Berthing Facility *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Keamanan dan Keselamatan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Akses untuk Distribusi Pembangunan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Akses untuk publik/Crew *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Potensi Pengembangan Bisnis *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Periode Pembangunan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Jarak ke Pembangkit *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Kompleksitas Peralatan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

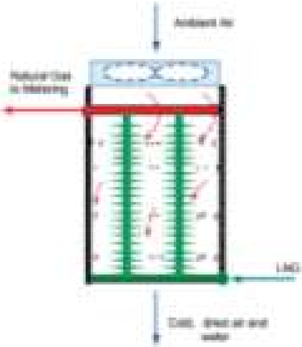
After section 7 Continue to next section

Section 8 of 13

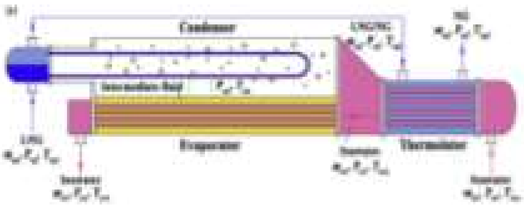
KUISIONER PENENTUAN LNG VAPORIZER

Pada Tugas akhir ini akan mendesain konseptual rantai pasok LNG dengan memilih teknologi LNG Vaporizer yang tepat untuk wilayah kalimantan barat. Pada sistem ini terdapat dua pembangkit gas yaitu, PLTG MPP jungkat 100 MW yang berlokasi di kabupaten Siantan dan PLTG Siantan 30 MW yang berlokasi di kota pontianak. Dalam tugas akhir ini direncanakan akan dibangun satu buah fasilitas LNG Vaporizer untuk meregasifikasi LNG yang akan di pasok untuk dua pembangkit gas di sistem tersebut. untuk pemilihan teknologi LNG Vaporizer terdapat 4 alternatif yaitu,

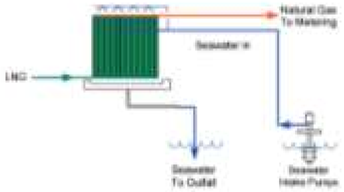
Ambient Air Vaporizer (AAV)



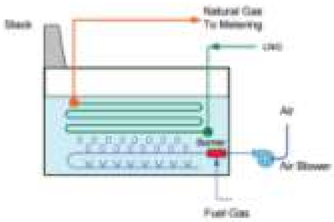
Intermediate Fluid Vaporizer



Open Rack Vaporizer



Submerged Combustion Vaporizer



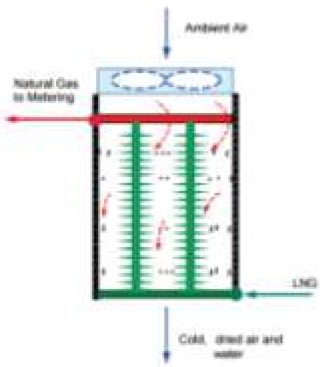
After section 8 Continue to next section

Section 9 of 13

Ambient Air Vaporizer (AAV)

Teknologi AAV menggunakan udara sebagai sumber panas dalam meregasifikasi LNG menjadi Natural Gas. Teknologi ini berbentuk vertikal dengan equipment lebih banyak yang cocok untuk pembangkit peaker dan terminal LNG skala kecil. Teknologi AAV dalam performanya tergantung pada Suhu, Kelembaban, ketinggian daerah, angin, radiasi sinar matahari, dan lokasi.

Image title

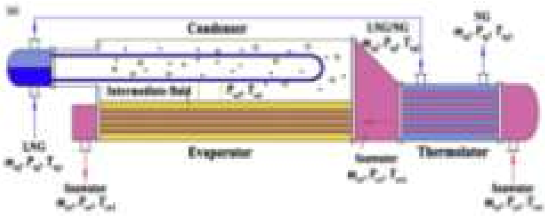


Section 10 of 13

Intermediate Fluid Vaporizer - Glycol Water (IFV)

Teknologi IFV menggunakan Glycol water sebagai media heat transfer karena memiliki titik beku yang rendah. Teknologi memiliki energi effisiensi yang lebih baik, tidak sensitif terhadap lingkungan ambient dan tidak terjadi pembekuan dalam pipa saat pertukaran panas. IFV memiliki equipment yang lebih kompleks karena menggunakan glycol water.

Image title

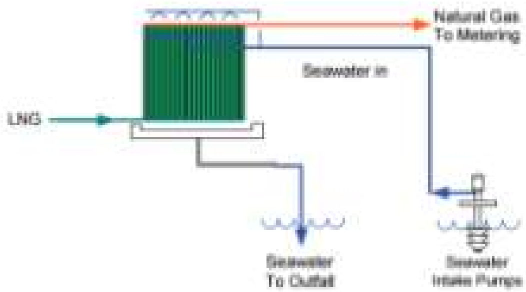


Section 11 of 13

Open Rack Vaporizer (ORV)

Teknologi ORV menggunakan air laut sebagai media penukar panas. Teknologi ORV memiliki equipment yang lebih simple dibanding teknologi yang lain. Teknologi ORV membutuhkan air laut dengan kualitas yang baik untuk operasi.

Image title

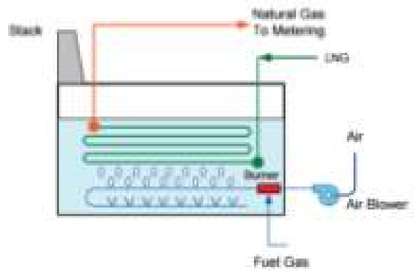


Section 12 of 13

Submerged Combustion Vaporizer (SCV)

Teknologi SCV menggunakan water bath yang dipanaskan dengan hot flue gas untuk menghindari pembekuan. Teknologi SCV memiliki safety yang sangat baik. Teknologi SCV menghasilkan emisi dari pembakaran hot flue gas

Image title



Biaya Kapital *

Biaya Kapital adalah biaya yang dikeluarkan untuk membeli seluruh kebutuhan aset utama dan aset penunjang.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Biaya Operasional *

Biaya Operasional adalah biaya yang dikeluarkan untuk menunjang operasional kerja aset.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Biaya Perawatan *

Biaya Perawatan adalah biaya yang dikeluarkan untuk merawat aset

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Proven Technology *

Merupakan ketersediaan teknologi pada aset

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Ketersediaan Sumber Panas *

Merupakan ketersediaan media penukar panas pada LNG Vaporizer

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Ketersediaan Spare Part *

Merupakan ketersediaan suku cadang pada teknologi LNG Vaporizer.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Fluktuasi Beban *

Merupakan Kemampuan LNG Vaporizer dalam bekerja dengan beban yang fluktuatif

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Kompleksitas Peralatan *

Merupakan tingkat kesederhanaan komponen LNG Vaporizer.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Faktor Lingkungan *

Merupakan aspek yang mempengaruhi kinerja LNG Vaporizer berupa kelembaban, temperatur, iklim, kecepatan angin

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Geografis Area *

Merupakan Kondisi daerah yang mempengaruhi kinerja LNG Vaporizer seperti ketersediaan air laut.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Tingkat Polusi *

Tingkat kebersihan udara pada daerah tersebut.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Kemudahan Operasional *

Tingkat kemudahan dalam mengoperasikan LNG Vaporizer.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Kemudahan Perawatan *

Tingkat Kemudahan dalam merawat LNG Vaporizer.

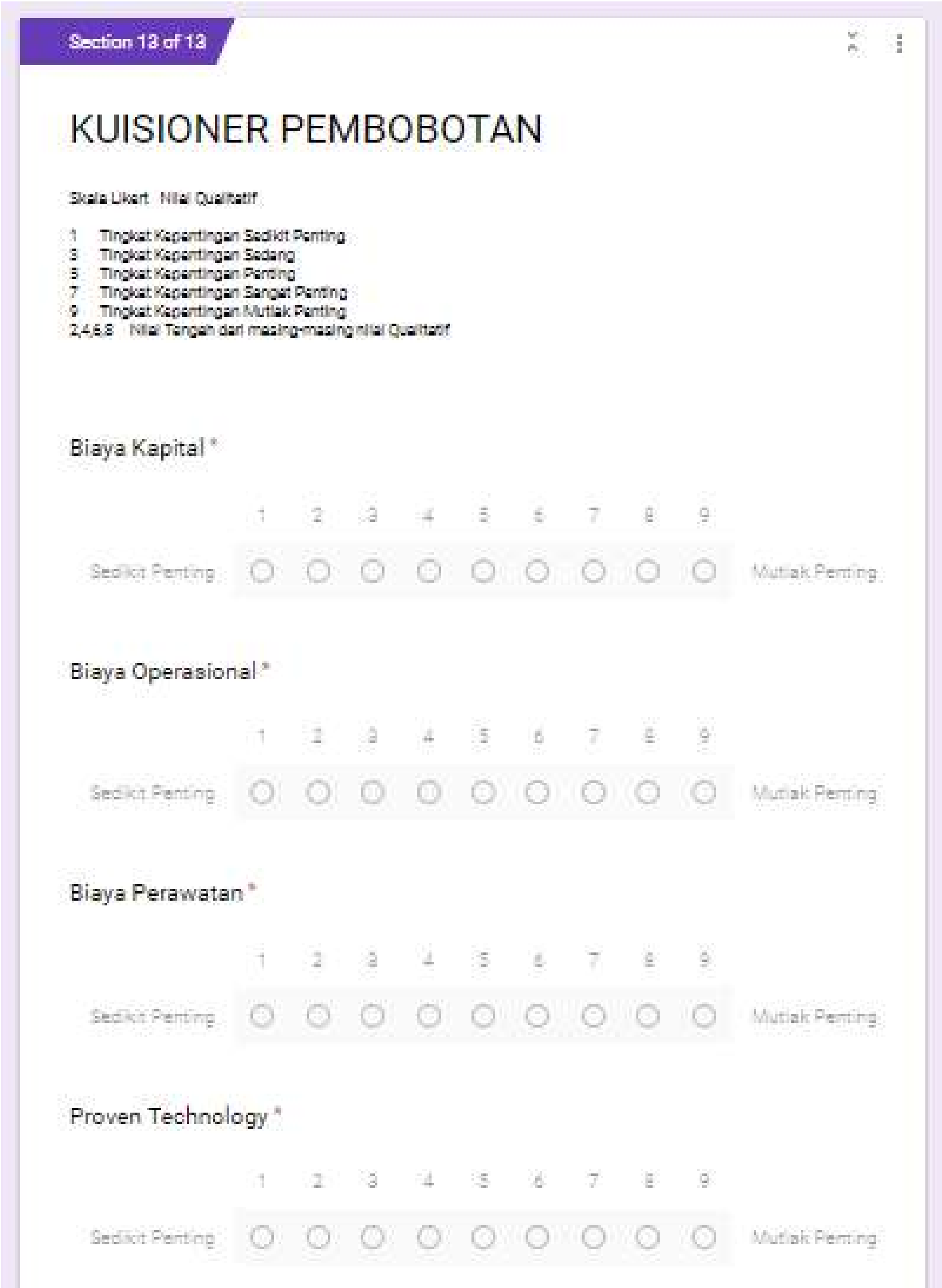
	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

Tingkat Keselamatan Operasional *

Tingkat keselamatan dalam mengoperasikan LNG Vaporizer.

	1	2	3	4	5	
Sangat Buruk	○	○	○	○	○	Sangat Baik

After section 12 Continue to next section



Section 13 of 13

KUISIONER PEMBOBOTAN

Skala Likert Nilai Qualitatif

1 Tingkat Kepentingan Sedikit Penting
3 Tingkat Kepentingan Sedang
5 Tingkat Kepentingan Penting
7 Tingkat Kepentingan Sangat Penting
9 Tingkat Kepentingan Mutlak Penting
2,4,6,8 Nilai Tengah dari masing-masing nilai Qualitatif

Biaya Kapital *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Biaya Operasional *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Biaya Perawatan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Proven Technology *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Ketersediaan Spare Part *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Fluktuasi Beban *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Jumlah Equipment *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Faktor Lingkungan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Geografis Area *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Tingkat Polusi *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Kemudahan Operasional *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Kemudahan Perawatan *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Tingkat Keselamatan Operasional *

	1	2	3	4	5	6	7	8	9	
Sedikit Penting	○	○	○	○	○	○	○	○	○	Mutlak Penting

Attachment C

Validation Test Result

1. Plant Sitting Quesioner

Resp	Siantan Regency													Total
	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component	
Res 1	5	5	3	5	3	3	5	3	3	3	2	4	4	48
Res 2	3	3	4	5	4	3	4	5	4	4	4	4	4	51
Res 3	2	2	4	4	2	2	1	4	4	4	4	3	3	39
Res 4	5	5	5	5	5	4	5	5	5	5	5	5	3	62
Res 5	3	3	3	3	3	3	3	3	3	3	3	3	4	40
Res 6	2	3	3	4	4	2	3	4	2	3	4	3	3	40
Res 7	3	3	4	4	4	3	5	4	3	5	4	4	2	48
Res 8	2	2	4	4	4	4	5	5	4	4	4	4	3	49

Res 9	2	2	3	2	1	3	2	1	1	4	3	4	4	32
Res 10	4	5	3	5	4	2	4	5	3	3	1	4	3	46
Res 11	4	3	3	3	4	3	3	3	3	4	3	3	3	42
Res 12	5	3	4	4	4	4	3	4	4	4	4	4	4	51
Res 13	2	3	2	2	3	3	4	4	4	5	3	3	3	41
Res 14	4	4	2	3	3	2	4	2	2	3	3	3	2	37
Res 15	3	2	3	4	3	3	3	3	3	2	3	4	3	39
Res 16	5	5	5	5	5	5	5	5	5	5	4	4	4	62
Res 17	2	4	4	4	4	4	4	4	4	4	4	4	4	50
Res 18	5	4	3	3	4	4	3	4	4	5	4	3	4	50
Res 19	3	4	3	4	1	3	2	4	4	3	3	3	4	41
Res 20	4	3	4	3	3	3	4	4	4	3	2	3	4	44
Res 21	1	1	1	1	1	1	1	1	1	1	1	1	1	13
Res 22	3	4	3	4	5	4	5	4	3	5	4	4	3	51

Res 23	4	3	3	2	2	3	4	4	3	3	4	4	4	43
Res 24	5	5	4	5	2	4	4	2	2	4	4	4	5	50
Res 25	2	1	4	2	2	5	2	4	1	3	3	4	3	36
Res 26	4	5	3	3	4	1	3	3	4	4	3	3	3	43
Res 27	3	3	4	4	3	4	2	2	3	4	3	4	5	44
Res 28	5	5	4	4	4	4	4	4	3	4	5	3	3	52
Res 29	4	3	4	3	4	3	5	5	5	5	3	5	5	54
Res 30	4	3	4	4	3	2	4	3	3	3	4	3	4	44
Validity	0,657	0,652	0,765	0,713	0,751	0,590	0,734	0,690	0,725	0,729	0,601	0,708	0,480	
Result	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	

Re sp	Pontianak City													T ot al
	Land Cost	Dredging Cost	Operati onal Cost	Capi tal Cost	Berthi ng Cost	Permi t Cost	Safety & Securit y	Access for Distribut ion	Acces s for Crew	Business Potentia l	Period of Constr uction	Distanc es to Power Plant	Comple xity of Compo nent	
Re s 1	2	2	3	5	3	2	2	4	4	5	4	2	4	4 2
Re s 2	2	2	3	4	3	2	4	3	3	5	4	3	4	4 2
Re s 3	2	4	4	4	4	3	1	4	4	4	4	4	2	4 4
Re s 4	5	5	5	5	5	3	5	5	5	5	5	5	4	6 2
Re s 5	3	3	3	3	3	3	3	3	3	3	3	3	3	3 9
Re s 6	3	3	3	4	4	4	3	4	2	4	4	3	3	4 4
Re s 7	4	3	4	4	4	2	3	4	4	3	4	3	4	4 6
Re s 8	2	3	3	3	3	3	2	4	5	5	4	4	2	4 3
Re s 9	2	4	5	4	5	4	4	5	4	5	5	4	2	5 3

Res 10	3	5	4	5	4	2	4	5	5	3	2	3	2	47
Res 11	2	2	2	3	3	3	3	2	3	3	2	2	3	33
Res 12	5	4	5	4	5	4	4	4	4	5	4	4	4	56
Res 13	2	2	3	3	4	2	4	4	5	5	2	3	4	43
Res 14	3	2	3	3	4	4	3	4	3	4	5	4	3	45
Res 15	2	3	2	3	3	2	4	4	4	4	3	3	3	40
Res 16	5	5	5	5	5	5	5	5	5	5	4	5	4	63
Res 17	2	4	4	4	4	4	4	4	4	4	4	4	4	50
Res 18	4	3	5	3	3	4	5	3	2	5	3	2	4	46
Res 19	2	4	3	3	2	4	1	4	3	3	3	3	4	39

Res 20	3	3	3	3	3	4	3	3	3	3	2	3	4	40
Res 21	1	1	3	1	1	3	3	3	3	3	1	3	1	27
Res 22	4	4	5	4	5	4	5	4	5	4	4	4	4	56
Res 23	3	3	3	2	2	2	3	5	5	4	4	3	3	42
Res 24	2	2	4	5	3	2	2	4	4	4	2	3	5	42
Res 25	2	2	4	2	1	1	3	4	4	5	3	4	3	38
Res 26	2	3	4	3	3	2	2	4	5	2	4	3	3	40
Res 27	2	2	4	4	3	1	1	5	5	5	4	3	4	43
Res 28	5	4	4	4	4	4	4	4	3	4	4	4	4	52
Res 29	3	3	4	4	4	4	5	5	5	5	4	4	4	54

Res 30	5	5	4	4	3	4	3	4	4	4	4	2	4	50

Validity	0,751	0,744	0,757	0,681	0,830	0,489	0,592	0,610	0,400	0,482	0,637	0,632	0,403
Result	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Resp	Offshore (Mini FSRU)													Total
	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component	
Res 1	5	5	1	2	5	3	4	2	1	5	5	2	1	41
Res 2	1	1	3	4	1	3	5	5	5	5	3	4	2	42
Res 3	5	2	3	3	2	4	5	2	2	4	4	2	2	40
Res 4	5	5	5	5	5	3	5	5	5	5	5	5	3	61
Res 5	3	3	3	3	3	2	3	3	3	3	3	3	2	37
Res 6	1	1	4	3	1	3	3	4	4	3	3	4	2	36
Res 7	1	2	4	5	5	4	5	5	5	4	2	5	2	49
Res 8	5	5	5	1	2	3	5	4	2	4	5	3	1	45
Res 9	5	4	5	5	4	2	4	3	2	5	4	3	3	49
Res 10	3	4	5	5	3	3	5	5	5	3	5	1	3	50
Res 11	2	5	4	2	4	4	2	4	1	4	3	2	3	40
Res 12	4	4	4	4	4	2	4	4	4	4	4	4	2	48
Res 13	4	3	2	2	4	3	5	2	2	3	2	2	2	36
Res 14	4	5	3	1	3	4	4	4	4	4	1	1	3	41

Res 15	2	2	2	1	3	2	4	3	3	3	3	3	5	36
Res 16	5	5	5	5	5	5	5	5	5	5	4	5	5	64
Res 17	2	4	4	4	4	4	4	4	4	4	4	4	4	50
Res 18	5	4	5	2	5	4	4	4	3	5	3	3	5	52
Res 19	5	4	2	2	5	4	5	2	3	4	3	2	2	43
Res 20	5	5	2	2	2	4	4	4	3	3	5	3	2	44
Res 21	5	5	5	1	5	3	5	5	3	5	5	3	3	53
Res 22	5	5	4	4	5	4	5	5	4	5	4	4	4	58
Res 23	5	4	4	3	3	2	4	2	3	3	4	3	4	44
Res 24	5	5	2	1	3	4	5	4	4	4	4	1	1	43
Res 25	4	1	3	2	1	1	3	3	2	3	3	2	3	31
Res 26	3	2	2	2	2	2	4	3	2	3	3	3	3	34
Res 27	5	5	2	1	4	4	5	2	2	2	4	2	2	40
Res 28	5	5	5	5	3	5	5	4	3	4	5	3	3	55

Res 29	5	5	5	3	3	2	3	3	3	4	4	3	4	47
Res 30	5	5	5	4	5	5	4	3	3	4	3	5	5	56
Validity	0,372	0,585	0,697	0,608	0,627	0,517	0,426	0,569	0,512	0,638	0,424	0,554	0,435	
Result	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	

2. LNG Vaporizer

Resp	Ambient Air Vaporizer							Ambient Air Vaporizer							Total
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Area Geographic	Polution	Ease of Operational	ease of maintenance	safety Operational	
Res 1	3	4	3	2	5	2	3	4	2	2	5	5	4	5	49
Res 2	2	2	2	2	1	3	3	3	1	3	1	4	3	4	34
Res 3	4	4	4	3	4	4	2	4	4	4	4	4	3	4	52
Res 4	5	5	5	3	5	5	1	5	5	5	1	1	1	3	50
Res 5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42
Res 6	3	2	3	3	4	2	2	3	3	4	2	2	2	4	39
Res 7	5	4	5	4	3	4	3	4	5	4	4	4	3	4	56
Res 8	4	5	5	4	5	3	4	4	4	5	5	5	4	4	61
Res 9	3	3	3	4	3	3	3	4	3	4	3	3	3	3	45
Res 10	2	5	5	5	5	5	5	5	5	5	5	5	5	5	67
Res 11	4	4	4	3	3	4	2	4	2	3	4	4	4	4	49

Res 12	4	4	4	3	4	4	4	4	5	5	4	4	4	4	57
Res 13	3	4	2	5	4	3	3	3	4	4	2	2	4	3	46
Res 14	3	4	2	3	4	3	3	3	3	3	2	2	2	3	40
Res 15	2	3	3	2	2	3	3	3	2	3	3	3	3	3	38
Res 16	5	5	5	5	5	5	5	5	5	4	3	3	3	5	63
Res 17	4	4	4	4	4	4	4	4	4	4	4	4	4	4	56
Res 18	4	3	4	5	3	4	3	5	4	5	3	4	2	4	53
Res 19	3	3	4	2	2	2	3	4	1	1	1	4	4	3	37
Res 20	4	4	4	4	4	3	3	4	4	4	4	4	4	4	54
Res 21	5	5	1	3	1	5	3	5	1	1	5	5	5	3	48
Res 22	3	3	3	4	4	4	3	4	3	3	4	4	4	4	50
Res 23	4	4	4	4	4	3	2	5	3	3	5	4	4	4	53
Res 24	3	4	4	2	5	2	2	4	2	2	5	4	5	4	48
Res 25	5	5	5	5	4	5	4	5	2	4	5	5	5	5	64

Res 26	3	3	3	3	3	3	3	3	4	4	4	3	3	3	45
Res 27	5	5	4	5	5	4	2	5	2	4	4	4	4	5	58
Res 28	5	5	5	4	3	3	3	4	3	4	3	5	4	5	56
Res 29	4	4	5	5	5	3	3	5	5	5	5	3	5	4	61
Res 30	4	4	3	3	4	5	4	4	4	4	4	4	4	4	55

Validity	0,571	0,752	0,706	0,720	0,611	0,577	0,471	0,721	0,566	0,568	0,643	0,433	0,443	0,677
Result	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Res	Teknologi Intermediate Fluid Vaporizer														Total
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Area Geographic	Polution	Ease of Operational	ease of maintenance	safety Operational	
Res 1	3	4	3	4	1	1	3	2	5	2	5	4	4	2	43
Res 2	4	4	4	5	5	3	4	2	4	4	1	3	3	3	49
Res 3	2	2	2	4	3	3	4	4	3	3	3	2	2	4	41
Res 4	3	3	3	5	5	5	5	3	3	3	5	5	5	3	56
Res 5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42
Res 6	4	3	3	4	3	3	4	2	4	3	2	3	3	4	45
Res 7	4	3	4	3	4	4	3	4	3	3	4	4	3	4	50
Res 8	5	4	2	5	3	3	4	1	1	3	2	3	1	3	40
Res 9	1	3	3	3	3	3	4	3	5	3	3	3	3	3	43
Res 10	3	3	3	3	3	3	3	3	3	3	3	3	3	4	43
Res 11	3	4	3	5	5	5	5	5	5	5	5	5	3	4	62

Res 12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	56
Res 13	2	2	2	4	3	2	2	3	4	2	3	2	2	4	37
Res 14	3	3	2	4	3	3	3	4	3	5	2	3	3	4	45
Res 15	3	3	3	3	3	2	3	3	4	3	3	3	2	3	41
Res 16	5	5	5	5	5	5	5	4	5	3	3	5	5	5	65
Res 17	4	4	4	4	4	4	4	4	4	4	4	4	4	4	56
Res 18	4	5	5	4	3	4	5	4	3	4	5	4	4	5	59
Res 19	2	2	3	4	4	3	4	2	4	4	4	2	3	3	44
Res 20	2	2	2	3	3	3	4	3	3	2	3	3	3	3	39
Res 21	3	3	1	5	5	5	5	1	5	5	5	3	3	5	54
Res 22	4	4	4	3	3	3	4	3	3	3	3	3	3	3	46
Res 23	2	3	3	4	4	3	4	3	3	2	3	3	3	3	43
Res 24	3	2	3	2	2	2	3	2	5	5	5	3	3	3	43
Res 25	3	3	4	4	5	3	5	1	5	5	3	5	4	5	55

Res 26	3	3	3	3	3	3	3	3	4	4	4	3	3	3	45
Res 27	2	3	3	3	4	3	5	3	4	4	3	4	2	3	46
Res 28	4	4	4	5	4	4	4	3	4	5	4	4	3	3	55
Res 29	4	4	4	4	4	4	4	5	5	5	5	5	4	5	62
Res 30	4	4	4	4	4	4	3	2	4	2	3	3	3	4	48

Validity	0,512	0,673	0,605	0,515	0,656	0,791	0,641	0,415	0,403	0,527	0,458	0,825	0,702	0,611
Result	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Resp	Teknologi Open Rack Vaporizer														Total
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Area Geographic	Polution	Ease of Operational	ease of maintenance	safety Operational	
Res 1	5	5	1	4	5	5	3	5	1	1	5	4	1	2	47
Res 2	1	1	3	4	4	3	4	3	3	4	2	4	3	4	43
Res 3	4	4	2	4	5	4	4	4	5	4	4	4	4	4	56
Res 4	5	3	5	3	3	5	1	5	5	5	1	3	3	3	50
Res 5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42
Res 6	3	3	3	4	3	3	4	2	4	2	3	3	3	4	44
Res 7	4	3	4	3	4	4	3	3	3	4	3	4	3	4	49
Res 8	3	4	4	5	3	3	2	3	1	2	3	4	4	3	44
Res 9	4	5	2	2	3	2	2	3	5	4	3	5	1	3	44
Res 10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	28

Res 11	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42
Res 12	4	4	4	4	4	4	4	4	3	3	4	3	4	4	53
Res 13	5	4	4	4	4	5	4	4	4	3	4	4	3	5	57
Res 14	4	3	3	3	3	3	3	3	2	3	3	1	4	4	42
Res 15	3	3	3	3	2	4	3	4	2	2	2	3	3	3	40
Res 16	5	5	5	4	5	5	5	5	5	4	3	4	5	5	65
Res 17	4	4	4	4	4	4	4	4	4	4	4	4	4	4	56
Res 18	5	4	4	4	2	3	4	5	2	5	3	4	3	4	52
Res 19	3	4	3	4	5	3	4	4	5	4	5	3	3	3	53
Res 20	3	3	3	3	3	3	3	3	3	3	4	4	3	3	44
Res 21	1	3	3	5	5	5	5	3	1	1	3	3	3	3	44
Res 22	4	5	4	4	4	4	3	4	4	4	4	4	4	3	55
Res 23	2	2	3	4	4	3	4	4	4	2	4	4	4	4	48
Res 24	4	5	2	5	4	3	3	5	4	3	5	5	1	4	53

Res 25	3	4	2	5	5	5	5	3	5	5	5	5	3	5	60
Res 26	3	3	3	3	3	3	3	3	4	4	4	3	3	3	45
Res 27	4	4	4	5	4	4	4	4	2	3	4	3	4	4	53
Res 28	5	5	5	5	5	5	5	5	5	5	5	5	5	5	70
Res 29	4	4	4	4	4	4	5	5	5	5	5	5	5	5	64
Res 30	3	4	5	4	3	4	5	4	4	3	4	4	5	5	57

Validity	0,562	0,638	0,508	0,589	0,628	0,636	0,643	0,690	0,607	0,590	0,598	0,614	0,557	0,768
Result	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Resp	Teknologi Submerged Combustion Vaporizer														Total
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Area Geographic	Polution	Ease of Operational	ease of maintenance	safety Operational	
Res 1	2	2	3	3	5	4	5	3	3	3	2	4	4	4	47
Res 2	3	3	2	3	3	3	3	3	3	3	3	3	3	3	41
Res 3	1	1	2	4	2	2	2	2	3	3	2	2	2	2	30
Res 4	5	5	5	1	5	5	5	4	5	5	1	1	1	3	51
Res 5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42
Res 6	3	3	3	3	2	3	4	3	2	3	5	3	3	3	43
Res 7	4	4	3	4	4	4	3	3	3	4	4	3	4	3	50
Res 8	2	3	4	5	4	4	4	3	1	1	1	5	5	4	46
Res 9	1	2	2	2	4	3	4	4	3	3	3	2	2	5	40
Res 10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	28
Res 11	3	3	3	4	3	3	3	3	5	3	4	3	3	4	47
Res 12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	56

Res 13	3	2	2	4	3	3	3	4	4	4	1	3	2	4	42
Res 14	3	2	4	3	3	4	4	2	3	4	4	2	1	3	42
Res 15	2	3	2	5	5	3	3	3	4	4	3	3	2	2	44
Res 16	5	5	5	5	4	5	5	5	3	3	3	5	5	5	63
Res 17	4	4	4	4	4	4	4	4	4	4	4	4	4	4	56
Res 18	4	2	4	4	5	4	4	3	4	3	5	4	3	4	53
Res 19	3	3	3	3	2	3	2	3	3	2	1	2	2	4	36
Res 20	2	2	2	3	2	3	4	2	2	3	3	2	2	3	35
Res 21	5	5	3	5	5	3	3	1	1	1	1	5	3	1	42
Res 22	3	3	3	4	4	3	3	4	3	4	3	3	4	4	48
Res 23	2	2	2	4	4	3	5	3	3	4	2	4	3	3	44
Res 24	3	2	4	4	5	4	4	1	5	5	1	3	3	4	48
Res 25	3	3	2	4	5	4	5	1	5	5	2	3	2	2	46
Res 26	3	3	3	3	3	3	3	3	4	4	4	3	3	3	45

Res 27	2	3	3	4	4	3	5	2	5	4	1	3	3	3	45
Res 28	3	3	3	4	3	3	3	2	2	3	2	3	3	5	42
Res 29	4	4	5	5	5	4	4	4	5	5	5	4	4	5	63
Res 30	4	4	4	4	4	4	4	4	4	4	4	4	4	4	56

Validity	0,678	0,639	0,773	0,418	0,641	0,805	0,558	0,563	0,456	0,446	0,421	0,580	0,624	0,524
Result	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Attachment D

Electre Implementation for Selection LNG Vaporizer & Location Criteria Combined

ELECTRE Implementation for Selection LNG Vaporizer & Location

1. Preference and Weight Data

Preference and Weight data in this section is also similar. The criteria and alternatives is combined.

Alternative LNG Vaporizer + Location

Alternative	Vaporizer Technology in Location
1	Ambient Air Vaporizer located in Siantan
2	Intermediate Fluid Vaporizer located in Siantan
3	Open Rack Vaporizer located in Siantan
4	Submerged Combustion Vaporizer Located in Siantan
5	Ambient Air Vaporizer Located in Pontianak
6	Intermediate Fluid Vaporizer Located in Pontianak
7	Open Rack Vaporizer Located in Pontianak
8	Submerged Combustion Vaporizer Located in Pontianak
9	Ambient Air Vaporizer Located in Mini FSRU
10	Intermediate Fluid Vaporizer Located in Mini FSRU
11	Open Rack Vaporizer Located in Mini FSRU
12	Submerged Combustion Vaporizer Located in Mini FSRU

To implement the selection LNG Vaporizer and Location, the same preference and weight data scale is also used in Electre Implementation. The preference and weight data is taken from the questionnaire as shown in tables below.

Preference and Weight of Vaporizer

Criteria	Alternative				Weight
	AAV	IFV	ORV	SCV	
Capital Cost	3,00	3,00	4,00	3,00	7,00
Operational Cost	4,00	3,00	4,00	3,00	8,00
Maintenance Cost	4,00	3,00	3,00	3,00	8,00
Proven Technology	3,00	4,00	4,00	4,00	7,00
Availability of Heat Source	4,00	3,00	4,00	4,00	7,00
Availability of Spare Part	3,00	3,00	3,00	3,00	8,00
Fluctuation Load	3,00	4,00	3,00	4,00	7,00
Equipment complexity	4,00	3,00	3,00	3,00	6,00
EnvironmentalFactor	4,00	4,00	5,00	3,00	7,00
Geographic Area	4,00	3,00	4,00	3,00	7,00
Pollution	4,00	3,00	4,00	3,00	7,00
Ease of Operational	4,00	3,00	4,00	3,00	7,00
Ease of Maintenance	4,00	3,00	3,00	3,00	7,00
Safety Operation	4,00	3,00	4,00	4,00	9,00

Preference of Criteria Value of Location Selection

Criteria	Alternative			Weight
	Siantan Regency	Pontianak City	Offshore (Mini FSRU)	
Land and Preparation cost	4,00	2,00	5,00	7
Dredging Cost	3,00	3,00	5,00	7
Operational Cost	4,00	3,00	5,00	9
Capital Cost	4,00	4,00	2,00	7
Berthing Facility	4,00	3,00	5,00	7
Permission Cost	3,00	4,00	4,00	7
Safety and Security	4,00	3,00	5,00	9
Access for Distribution	4,00	4,00	4,00	9
Access for crew	3,00	4,00	3,00	7
Future business development	4,00	5,00	4,00	9
Periode of Construction	4,00	4,00	3,00	7
Distance to Power Plant	4,00	3,00	3,00	7
Equipment complexity	4,00	4,00	2,00	5

Result

Step 1: Normalize

$$\frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \text{ for i = 1,2,3,.... m and j = 1,2,3... n}$$

By using this formula of normalize, the value of each criteria can be concluded as shown in Table 4.46 below.

The value of each criteria

alternative	Criteria of vaporizer & Location				
	Capital Cost	Operational Cost	Maintenance Cost	....	Complexity of Component
AAV in Siantan	9,00	16,00	16,00	....	16,00
IFV in Siantan	9,00	9,00	9,00	....	16,00
ORV in Siantan	16,00	16,00	9,00	....	16,00
SCV in Siantan	9,00	9,00	9,00	....	16,00
AAV in Pontianak	9,00	16,00	16,00	....	16,00
IFV in Pontianak	9,00	9,00	9,00	....	16,00
ORV in Pontianak	16,00	16,00	`	....	16,00
SCV in Pontianak	9,00	9,00	9,00	....	16,00
AAV in Mini FSRU	9,00	16,00	16,00	....	4,00
IFV in Mini FSRU	9,00	9,00	9,00	....	4,00
ORV in Mini FSRU	16,00	16,00	9,00	....	4,00
SCV in Mini FSRU	9,00	9,00	9,00	....	4,00
SUM	129,00	150,00	120,00	....	144,00

Alternative	Criteria of vaporizer & Location				
	Capital Cost	Operational Cost	Maintenance Cost	....	Complexity of Component
AAV in Siantan	0,26	0,33	0,37	....	0,33
IFV in Siantan	0,26	0,24	0,27	....	0,33
ORV in Siantan	0,35	0,33	0,27	....	0,33
SCV in Siantan	0,26	0,24	0,27	....	0,33
AAV in Pontianak	0,26	0,33	0,37	....	0,33
IFV in Pontianak	0,26	0,24	0,27	....	0,33
ORV in Pontianak	0,35	0,33	0,27	....	0,33
SCV in Pontianak	0,26	0,24	0,27	....	0,33

AAV in Mini FSRU	0,26	0,33	0,37	....	0,17
IFV in Mini FSRU	0,26	0,24	0,27	....	0,17
ORV in Mini FSRU	0,35	0,33	0,27	....	0,17
SCV in Mini FSRU	0,26	0,24	0,27	....	0,17

Step 2: Weighting Matriks Normalize

$$V = R \times W$$

$$\begin{matrix} v_{11} & v_{12} & v_{1n} \\ v_{21} & v_{22} & v_{2n} \\ v_{m1} & v_{m2} & v_{mn} \end{matrix} = \begin{matrix} w_1 r_{11} & w_2 r_{12} & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & w_n r_{2n} \\ w_1 r_{m1} & w_2 r_{m2} & w_n r_{mn} \end{matrix}$$

By using this formula it can be summarized in table.

Weight Matriks Normalize Value of LNG Vaporizer & Location Selection

Alternative	Criteria of vaporizer				
	Capital Cost	Operational Cost	Maintenance Cost	....	Complexity of Component
AAV in Siantan	1,85	2,61	2,56	....	1,67
IFV in Siantan	1,85	1,96	1,92	....	1,67
ORV in Siantan	2,47	2,61	1,92	....	1,67
SCV in Siantan	1,85	1,96	1,92	....	1,67
AAV in Pontianak	1,85	2,61	2,56	....	1,67
IFV in Pontianak	1,85	1,96	1,92	....	1,67
ORV in Pontianak	2,47	2,61	1,92	....	1,67
SCV in Pontianak	1,85	1,96	1,92	....	1,67
AAV in Mini FSRU	1,85	2,61	2,56	....	0,83
IFV in Mini FSRU	1,85	1,96	1,92	....	0,83
ORV in Mini FSRU	2,47	2,61	1,92	....	0,83
SCV in Mini FSRU	1,85	1,96	1,92	....	0,83

Absolute Different

No	Selisih Absolut	Capital Cost	Operational Cost	Maintenance Cost	....	Complexity of Component
1	A1-A2	0,00	0,65	0,64	....	0,00
2	A1-A3	0,62	0,00	0,64	....	0,00
3	A1-A4	0,00	0,65	0,64	....	0,00
4	A1-A5	0,00	0,00	0,00	....	0,00
5	A1-A6	0,00	0,65	0,64	....	0,00
6	A1-A7	0,62	0,00	0,64	....	0,00
7	A1-A8	0,00	0,65	0,64	....	0,00
8	A1-A9	0,00	0,00	0,00	....	0,83
9	A1-A10	0,00	0,65	0,64	....	0,83
10	A1-A11	0,62	0,00	0,64	....	0,83
11	A1-A12	0,00	0,65	0,64	....	0,83
....						
55	A7-A11	0,00	0,00	0,00	....	0,83
56	A7-A12	0,62	0,65	0,00	....	0,83
57	A8-A9	0,00	0,65	0,64	....	0,83
58	A8-A10	0,00	0,00	0,00	....	0,83
59	A8-A11	0,62	0,65	0,00	....	0,83
60	A8-A12	0,00	0,00	0,00	....	0,83
61	A9-A10	0,00	0,65	0,64	....	0,00
62	A9-A11	0,62	0,00	0,64	....	0,00
63	A9-A12	0,00	0,65	0,64	....	0,00
64	A10-A11	0,00	0,00	0,00	....	0,00
65	A10-A12	0,62	0,65	0,00	....	0,00
66	A11-A12	0,62	0,65	0,00	....	0,00

Step 3: Set of Concordances and Discordances

There are 66 concordances and discordances. Table below shows A1 to a_1 to a_2, a_1 to a_3, a_1 to a_4, a_1 to a_5, a_1 to a_6, and a_{11} to a_{12}.

Concordances and Discordances Value

A1 - A2

A1 to A2	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	7,00	8,00	7,00	0,00	7,00	8,00	0,00	6,00	7,00	7,00	7,00	7,00	9,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0	0	0	0,5353	0	0	0,57155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A2 to A1	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	7,00	0,00	0,00	7,00	0,00	8,00	7,00	0,00	7,00	0,00	0,00	0,00	0,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0	0,653197	0,6163156	0	0,535303	0	0	0,528271	0	0,5715	0,57155	0,6163156	0,688247	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A1 - A3

A1 To A3	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	0,00	8,00	7,00	0,00	7,00	8,00	7,00	6,00	0,00	7,00	7,00	7,00	9,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0,61632	0	0	0,5353	0	0	0	0	0,4974683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nilai Max																										

A3 To A1	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	7,00	8,00	0,00	7,00	7,00	8,00	7,00	0,00	7,00	7,00	7,00	0,00	9,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0	0	0,6163156	0	0	0	0	0,528271	0	0	0	0,6163156	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A1 - A4

A1 To A4	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	7,00	8,00	7,00	0,00	7,00	8,00	0,00	6,00	7,00	7,00	7,00	7,00	9,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0	0	0	0,5353	0	0	0,57155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A4 To A1	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	7,00	0,00	0,00	7,00	7,00	8,00	7,00	0,00	0,00	0,00	0,00	0,00	9,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0	0,653197	0,6163156	0	0	0	0	0,528271	0,4974683	0,5715	0,57155	0,6163156	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A11 - A12

A11 To A12	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	7,00	8,00	7,00	7,00	7,00	8,00	0,00	6,00	7,00	7,00	7,00	7,00	9,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0	0	0	0	0	0	0,57155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A12 To A11	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	0,00	0,00	7,00	7,00	7,00	8,00	7,00	6,00	0,00	0,00	0,00	7,00	9,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0,61632	0,653197	0	0	0	0	0	0	0,9949367	0,5715	0,57155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A10 - A12

A10 To A12	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	7,00	8,00	7,00	7,00	0,00	8,00	7,00	6,00	7,00	7,00	7,00	7,00	0,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A10 To A12	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	9,00	0,00	0,00	0,00	0,00	0,00	0,00
Disordance	0,61632	0,653197	0	0	0	0	0,57155	0	0,9949367	0,5715	0,57155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A10 - A11

A10 To A11	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	0,00	8,00	7,00	0,00	7,00	8,00	7,00	6,00	0,00	7,00	7,00	7,00	9,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

A10 To A11	Criteria of vaporizer													Criteria of Location												
	Capital Cost	Operational Cost	Maintenance Cost	Proven Technology	Heat source Availability	Spare Part Availability	Fluctuation Load	Equipment Complexity	Environment Factor	Polution	Ease of Operational	ease of maintenance	safety Operational	Land Cost	Dredging Cost	Operational Cost	Capital Cost	Berthing Cost	Permit Cost	Safety & Security	Access for Distribution	Access for Crew	Business Potential	Period of Construction	Distances to Power Plant	Complexity of Component
Concordance	7,00	8,00	7,00	7,00	0,00	8,00	7,00	6,00	7,00	7,00	7,00	7,00	0,00	7,00	7,00	9,00	7,00	7,00	7,00	9,00	9,00	7,00	9,00	7,00	7,00	5,00
Disordance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max Value																										

Step 4: Calculate Matriks Concordances and Discordances

a. Calculating the matrix concordance

$$C_{kl} = \sum_{je} w_j$$

By using this formula, all matrix in corcordance it can be summarized, with the result shown in Table below.

Concordances and Disordances A2 to A3

NILAI CONCORDANCE

ALTERNATIF	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9	Alt 10	Alt 11	Alt 12
Alt 1	0	133,00	171,00	142,00	152,00	94,00	147,00	103,00	145,00	107,00	145,00	116,00
Alt 2	177,00	0	184,00	184,00	138,00	152,00	145,00	145,00	151,00	165,00	158,00	158,00
Alt 3	170,00	139,00	0	184,00	131,00	100,00	152,00	116,00	144,00	113,00	165,00	129,00
Alt 4	177,00	175,00	184,00	0	133,00	136,00	145,00	152,00	151,00	149,00	158,00	165,00
Alt 5	168,00	110,00	148,00	177,00	0	133,00	171,00	142,00	156,00	138,00	136,00	107,00
Alt 6	154,00	168,00	161,00	161,00	177,00	0	184,00	184,00	142,00	156,00	149,00	149,00
Alt 7	147,00	116,00	168,00	132,00	177,00	139,00	0	155,00	135,00	104,00	156,00	120,00
Alt 8	152,00	152,00	161,00	168,00	177,00	175,00	184,00	0	142,00	140,00	149,00	156,00
Alt 9	145,00	87,00	152,00	96,00	177,00	94,00	132,00	103,00	0	133,00	171,00	142,00
Alt 10	131,00	145,00	138,00	138,00	138,00	152,00	145,00	145,00	177,00	0	175,00	9,00
Alt 11	124,00	158,00	145,00	109,00	131,00	100,00	152,00	116,00	170,00	170,00	0	155,00
Alt 12	177,00	129,00	138,00	145,00	138,00	136,00	145,00	152,00	177,00	175,00	184,00	0

b. Calculating the matrix discordances

It is mathematically written as follows:

$$d_{kl} = \frac{\max\{|v_{kj} - v_{ij}|\}}{\max\{|v_{kj} - v_{ij}|\}}$$

Matriks Discordances Calculate

NILAI DISORDANCE

ALTERNATIF	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9	Alt 10	Alt 11	Alt 12
Alt 1	0	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Alt 2	0,83	0	0,83	0,72	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Alt 3	1,00	1,00	0	0,57	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Alt 4	0,88	1,00	0,55	0	0,63	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Alt 5	0,58	0,66	0,59	0,55	0	1,00	1,00	0,94	0,75	0,75	0,75	0,75
Alt 6	0,58	0,61	0,58	0,58	0,83	0	0,90	0,72	0,75	0,75	0,75	0,75
Alt 7	0,59	0,66	0,58	0,95	0,87	1,00	0	1,00	0,75	0,75	0,75	0,75
Alt 8	0,58	0,66	0,58	0,58	0,88	1,00	0,62	0	0,75	0,75	0,75	0,75
Alt 9	0,91	0,91	1,00	0,55	0,00	1,00	1,00	1,00	0	1,00	1,00	1,00
Alt 10	0,91	0,91	1,00	1,00	1,00	1,00	1,00	1,00	0,90	0	1,00	1,00
Alt 11	0,91	1,00	0,91	1,00	1,00	1,00	1,00	1,00	1,00	0,43	0	1,00
Alt 12	0,49	0,91	1,00	1,00	1,00	1,00	1,00	1,00	0,94	0,00	0,57	0

Step 5: Determine Dominant Matriks Concordances and Discordances

b. Calculating the dominant matrix concordance

$$C_{kl} >= C$$

with a threshold value (c) are:

$$c = \frac{\sum_{k=1}^{m}\sum_{i=1}^{m} c_{kl}}{m\,(m-1\,)}$$

Threshold Concordances = 146,265

so, that the elements of the matrix F are determined as follow:

$$f_{kl} = \{\frac{1, if\ c_{kl} \geq c}{0, if\ c_{kl} < c}$$

Matriks Concordances Threshold

MENGHITUNG NILAI MATRIKS DOMINAN CONCORDANCE

ALTERNATIF	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9	Alt 10	Alt 11	Alt 12
Alt 1	0	0	1	0	1	0	1	0	0	0	0	0
Alt 2	1,00	0	1,00	1,00	0,00	1,00	0,00	0,00	1,00	1,00	1,00	1,00
Alt 3	1,00	1	0,00	1,00	0,00	0,00	1,00	0,00	0,00	0,00	1,00	0,00
Alt 4	1,00	1	1,00	0,00	0,00	0,00	0,00	1,00	1,00	1,00	1,00	1,00
Alt 5	1,00	1	1,00	1,00	0,00	0,00	1,00	0,00	1,00	0,00	0,00	0,00
Alt 6	1,00	0	1,00	1,00	1,00	0,00	1,00	1,00	0,00	1,00	1,00	1,00
Alt 7	1,00	1	1,00	0,00	1,00	0,00	0,00	1,00	0,00	0,00	1,00	0,00
Alt 8	1,00	1	1,00	1,00	1,00	1,00	1,00	0,00	0,00	0,00	1,00	1,00
Alt 9	0,00	1	1,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
Alt 10	0,00	1	0,00	0,00	0,00	1,00	0,00	0,00	1,00	0,00	1,00	0,00
Alt 11	0,00	1	0,00	0,00	0,00	0,00	1,00	0,00	1,00	1,00	0,00	1,00
Alt 12	1,00	1	0,00	0,00	0,00	0,00	0,00	1,00	1,00	1,00	1,00	0,00

Calculating the dominant matrix concordance

Matrix G as the dominant matrix can be built with the help discordance threshold value:

$$d = \frac{\sum_{k=1}^{m} \sum_{i=1}^{m} d_{kl}}{m\ (m-1)}$$

Threshold Discordances = 0,910

and elements of the matrix G is determined as follows:

$$g_{kl} = \{\frac{1, if\ d_{kl} \geq c}{0, if\ d_{kl} < c}$$

Matriks Discordances Threshold

MENGHITUNG NILAI MATRIKS DOMINAN DISORDANCE

ALTERNATIF	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9	Alt 10	Alt 11	Alt 12
Alt 1	0	1	1	1	1	1	1	1	1	1	1	1
Alt 2	0	0	0	0	1	1	1	1	1	1	1	1
Alt 3	1	1	0	0	1	1	1	1	1	1	1	1
Alt 4	1	1	0	0	0	1	1	1	1	1	1	1
Alt 5	0	0	0	0	0	1	1	1	0	0	0	0
Alt 6	0	0	0	0	0	0	1	0	0	0	0	0
Alt 7	0	0	0	1	1	1	0	1	0	0	0	0
Alt 8	0	0	0	0	1	1	0	0	0	0	0	0
Alt 9	1	1	1	0	0	1	1	1	0	1	1	1
Alt 10	1	1	1	1	1	1	1	1	1	0	1	1
Alt 11	1	1	1	1	1	1	1	1	1	0	0	1
Alt 12	0	1	1	1	1	1	1	1	1	0	0	0

Step 6: Determine aggregate dominance matrix

The matrix E as aggregate dominance matrix is a matrix which each element is the multiplication between the matrix element F with the corresponding elements of the matrix G, mathematically expressed as:

$$E_{kl} = f_{kl}\ x\ g_{kl}$$

Matriks Discordances Threshold

MENENTUKAN AGREGAT DOMINAN MATRIKS

ALTERNATIF	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9	Alt 10	Alt 11	Alt 12
Alt 1	0	0	1	0	1	0	1	0	0	0	0	0
Alt 2	0	0	0	0	0	1	0	0	1	1	1	1
Alt 3	1	1	0	0	0	0	1	0	0	0	1	0
Alt 4	1	1	0	0	0	0	0	1	1	1	1	1
Alt 5	0	0	0	0	0	0	1	0	0	0	0	0
Alt 6	0	0	0	0	0	0	1	0	0	0	0	0
Alt 7	0	0	0	0	1	0	0	1	0	0	0	0
Alt 8	0	0	0	0	1	1	0	0	0	0	0	0
Alt 9	0	1	1	0	0	0	0	0	0	0	1	0
Alt 10	0	1	0	0	0	1	0	0	1	0	1	0
Alt 11	0	1	0	0	0	0	1	0	1	0	0	1
Alt 12	0	1	0	0	0	0	0	1	1	0	0	0

Step 7: Elimination less favorable alternative

Matrix E gives the preferred order of each alternative if AK is the better alternative than Al. Thus, the line in the matrix E which has the least number can be eliminated. Thus, the best alternative is the one that dominates the others. Based on Table 4.55, alternative 4 has the highest score and alternative 4 is the favourable alternative. Alternative s is Technology Submerged Combustion Vaporizer located in Siantan Regency.

Elimination less favourable Alternative

ALTERNATIF	VALUE
Alt 1	3
Alt 2	5
Alt 3	4
Alt 4	7
Alt 5	1
Alt 6	1
Alt 7	2
Alt 8	2
Alt 9	3
Alt 10	4
Alt 11	4
Alt 12	3

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AUTHOR BIODATA

The author was born in Batam on 11th June 1995, as the first child of 4 siblings. The author has completed the formal education in SDN 006 Sekupang Batam, SMPN 3 Batam, and SMAN 1 Batam. The author continued his study for bachelor degree in Marine Engineering Double Degree (DDME) program of Institut Teknologi Sepuluh Nopember and Hochschule Wismar, with student id number: 4213101007 and took area of expertise in Reliability Availability and Marine Safety (RAMS). During the college, the author was active in marine engineering student association (HIMASISKAL), 2014 - 2015 period, as staff of external affairs, the next year in 2015 – 2016 the author become head of external affairs department HIMASISKAL. In next year the author become RAMS Laboratory active member and contribute become project officer of Marine Safety International Conferences (Mastic 2018). The author has taken several job training in PT. ASL Shipyard Indonesia and PT. Pertamina RU V & MOR VI Balikpapan. On june, The author has also taken summer school at Maritime Simulation Centre Warnemunde (MSCW), Rostock, Germany.

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